9.0 CONSERVATION AND ENHANCEMENT MEASURES

FMPs must describe options to avoid, minimize, or compensate for adverse effects, and promote the conservation and enhancement of EFH, especially in habitat areas of particular concern.

Generally, non-water dependent actions should not be located in EFH if such actions may have adverse impacts on EFH. Activities that may result in significant adverse affects on EFH, should be avoided where less environmentally harmful alternatives are available. If there are no alternatives, the impacts of these actions should be minimized. Environmentally sound engineering and management practices should be employed for all actions which may adversely affect EFH. Disposal or spillage of any material (dredge material, sludge, industrial waste, or other potentially harmful materials) which would destroy or degrade EFH should be avoided. If avoidance or minimization is not possible, or will not adequately protect EFH, compensatory mitigation to conserve and enhance EFH should be recommended. FMPs may recommend proactive measures to conserve or enhance EFH. When developing proactive measures, Councils may develop a priority ranking of the recommendations to assist Federal and state agencies undertaking such measures.

FMPs should provide a variety of options to conserve or enhance EFH, which may include, but are not limited to:

(A) Enhancement of rivers, streams, and coastal areas. EFH located in, or influenced by, rivers, streams, and coastal areas may be enhanced by reestablishing endemic trees or other appropriate native vegetation on adjacent riparian areas; restoring natural bottom characteristics; removing unsuitable material from areas affected by human activities; or adding gravel or substrate to stream areas to promote spawning. Adverse effects stemming from upland areas that influence EFH may be avoided or minimized by employing measures such as, but not limited to, erosion control, road stabilization, upgrading culverts, removal or modification of operating procedures of dikes or levees to allow for fish passage, structural and operation measures at dams for fish passage and habitat protection, or improvement of watershed management. Initiation of Federal, state, or local government planning processes to restore watersheds associated with such rivers, streams, or coastal areas may also be recommended.

(B) Water quality and quantity. This category of options may include use of best land management practices for ensuring compliance with water quality standards at state and Federal levels, improved treatment of sewage, proper disposal of waste materials, and providing appropriate in-stream flow.

(C) Watershed analysis and planning. This may include encouraging local and state efforts to minimize destruction/degradation of wetlands**,** restore and maintain the ecological health of watersheds, and encourage restoration of native species. Any analysis of options should consider natural variability in weather or climatic conditions.

(D) Habitat creation. Under appropriate conditions, habitat creation (converting non-EFH to EFH) may be considered as a means of replacing lost or degraded EFH. However, habitat conversion at the expense of other naturally functioning systems must be justified within an ecosystem context.

The following sections of this EA analysis discuss and evaluate ways to avoid, minimize, or compensate for adverse effects, and promote the conservation and enhancement of EFH, especially in habitat areas of particular concern. Additional options to protect essential fish habitat will be proposed and analyzed in the future. Enhancement, restoration, and habitat creation programs may also be established. Potential impacts from non-fishing activities are monitored during the NMFS and State of Alaska permit review process, and development of habitat computer databases and GIS location maps will greatly assist this process.

9.1 Identification of Non-Fishing Activities Affecting EFH

9.1.1 Guidance from the Interim Final Rule

FMPs must be amended to identify activities that have the potential to adversely affect EFH quantity or quality, or both. Broad categories of activities which can adversely affect EFH include, but are not limited to: Dredging, fill, excavation, mining, impoundment, discharge, water diversions, thermal additions, actions that contribute to non-point source pollution and sedimentation, introduction of potentially hazardous materials, introduction of exotic species, and the conversion of aquatic habitat that may eliminate, diminish, or disrupt the functions of EFH. An FMP should describe the EFH most likely to be adversely affected by these or other activities. For each activity, the FMP should describe known and potential adverse impacts to EFH. The descriptions should explain the mechanisms or processes that may cause the adverse effects and how these may affect habitat function. A GIS or other mapping system should be used to support analyses of data. Maps geographically depicting impacts identified in this paragraph should be included in an FMP.

To the extent feasible and practicable, FMPs should analyze how fishing and non-fishing activities influence habitat function on an ecosystem or watershed scale. This analysis should describe the ecosystem or watershed; the dependence of the managed species on the ecosystem or watershed, especially EFH; and how fishing and non-fishing activities, individually or in combination, impact EFH and the managed species, and; how the loss of EFH may affect the ecosystem**.** An assessment of the cumulative and synergistic effects of multiple threats, including the effects of natural stresses (such as storm damage or climate-based environmental shifts), and an assessment of the ecological risks resulting from the impact of those threats on the managed species' habitat should also be included. For the purposes of this analysis, cumulative impacts are impacts on the environment that result from the incremental impact of an action when added to other past, present, and reasonably foreseeable future actions, regardless of who undertakes such actions. Cumulative impacts can result from individually minor, but collectively significant actions taking place over a period of time.

Essential fish habitat can be significantly altered by direct, cumulative, and/or environmental impacts. Direct impact to a defined essential fish habitat (EFH) will result in loss of its ability to provide specific habitat for a species. Loss of EFH will reduce the species ability to reproduce, survive, or exist. A cumulative impact can be minor, but if not monitored will contribute to the significant alteration of EFH over time. Equally important is an environmental impact which can also contribute to the loss of EFH.

9.1.2 Identification of Non-fishing Adverse Impacts to EFH in Alaska

An ***Adverse Impact***, by definition, means any impact which reduces quality and/or quantity of Essential Fish Habitat (EFH). A reduction of quality and/or quantity of EFH can be described by a direct, cumulative, and/or natural adverse impact. A ***direct impact*** to a defined essential fish habitat will result in loss of its ability to provide specific habitat for a species. ***Cumulative impacts*** are linked to the quantity and location of impacts within a given geographic area. For the purposes of this analysis, cumulative impacts are impacts on the environment that result from the incremental impact of an action when added to other past, present and reasonable foreseeable future action or threat[1], regardless of who undertakes such action. Impacts like these can build on one another, especially in developed areas or communities. Equally important are ***natural adverse impacts***, such as storm damage or climate-based

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[1] See attached **Non-fishing Adverse Impacts to Habitat** worksheet. The worksheet is an professional interpretative summary of broad category threats that are described in further detail throughout the Non-fishing Adverse Impacts Section.

environmental shifts, that can also contribute to the loss of EFH. Significant loss of EFH will reduce the species ability to reproduce, survive, or exist.

Species dependent on coastal areas during various stages of their life, particularly during juvenile rearing and adult reproduction, are more vulnerable to habitat alterations than are species that remain offshore. Also, the effects of habitat alteration on offshore species are not as apparent as they are in coastal areas. Concern is warranted, however, to the degree that (1) the offshore environment is subject to habitat degradation from either inshore activities or offshore uses, and (2) to the extent that some species living offshore depend directly or indirectly on coastal habitats for a critical life stage such as reproduction or as a source of food.

This section discusses types of activities that have a potential to cause habitat degradation that could affect fishery populations. This discussion is designed to identify those areas of uncertainty that may reasonably deserve attention in the future and not to be a conclusive review of impacts to EFH. Whether the likelihood and level of these activities or events cause harm to species habitats can be decided when the details of a proposed activity's location, magnitude, timing, and duration are more fully known. At present, human activities that adversely affect habitats are found near commercial fishing efforts, industrial growth areas, and community developments.

Dredging, Fill, Excavation

Potential impacts: excavation and maintenance of channels (includes disposal of excavated materials); construction of ports, mooring and cargo handling facilities; construction and operation of ship repair facilities; and construction of channel stabilization structures such as jetties and revetments.

Specific projects involving offshore marine disposals may directly impact EFH by overburdening and covering marine habitats. Because of the desirability of finding protection from Bering Sea storms, suitable port development sites often are valuable to the fishery fleet infrastructure. Recently, once such project in King Cove, Alaska, potentially could impact 20+ acres of marine habitat. This site was investigated and found not to be EFH for two species of crab, nevertheless the impact warranted investigation. Construction of a port facilities are planned for the City of Nome, Sand Point, and St. Paul, Alaska. In other areas, shallow water depth requires construction of long structures projected seaward in order to provide direct access from the uplands to deeper-draft ocean going vessels. These causeways alter the physical processes of the shoreline such as currents and disruption of fish migration. Another project in the village of Unalaska, required an extension of the airport runway into water depths approximately 50-feet, and received the necessary permits for construction. Beyond these specific projects, development activity in the coastal areas of the Bering Sea and the Aleutian Islands has been largely limited to construction of erosion control measures and breakwaters (e.g., the city of Bethel). As human population increase, so will the desire to have new harbor developments. In Alaska, there are over 40 known Ports of Call. Many villages lack large enough harbors for trade and therefore are not a port. All these require routine dredging ranging from 1-20 year intervals.

From a broad perspective, the environmental effects of dredging can include:

- Direct removal/burial of organisms as a result of dredging and placement of dredged material.
- Turbidity/siltation effects, including increased light attenuation from turbidity.
- Contaminant release and uptake, including nutrients, metals, and organics.

- Release of oxygen consuming substances.

- Noise disturbance to aquatic and terrestrial organisms.

- Alteration to hydrodynamic regimes and physical habitat.

Port expansion has become an almost continuous process due to economic growth, competition between ports, and significant increases in vessel size. Elimination or degradation of aquatic and upland habitats are commonplace since port expansion almost always requires the use of open water, submerged bottoms, and riparian zones. Ancillary port related activities and development often utilize even larger areas, many of which provide water quality and other functions needed to sustain living marine resources. Vessel repair facilities utilize highly toxic cleaners, paints, and lubricants that can contaminate waters and sediments. Modern pollution containment and abatement systems and procedures can prevent or minimize toxic substance releases; however, constant and diligent pollution control efforts must be implemented.

Even with the use of approved practices and disposal sites, ocean disposal of dredged materials is expected to cause environmental harm since contaminants will continue to be released, productive bottoms will still be filled, and localized turbidity plumes and reduced oxygen zones will persist. Dredging discharge increases turbidity and sediment--this is considered by some to be the most prevalent form of pollution in Alaska waters (Lloyd et al. 1987) and has contributed to the absence of grayling in some streams (LaPerriere et al. 1985). The effects of new disposal techniques such as creation of near shore berms and such “beneficial uses” of dredged material as creation of shallow water habitats and emergent wetlands are, in many cases, unclear and resulting long-term geomorphological and ecological change could be harmful to certain species and environments.

Return of materials dredged from the ocean to the water column is considered a discharge activity. Depending upon the chemical constituency of the local bottom sediments and any alterations of dredged materials prior to discharge, living marine resource in the area may be exposed to elevated levels of heavy metals. For example, scallop populations are vulnerable to pollution, even in offshore habitats where dumping and runoff can have an effect (Gould and Fowler 1991). Ocean dumping of sediments mat bury or damage scallops by abrasion and gill clogging (Larsen and Lee 1978). Scallops are efficient at concentrating PCB's and heavy metals, including silver, copper, and nickel (Pesch et al. 1979), mercury (Klein and Goldberg 1970), cadmium (Vattutone et al. 1976), chromium (Mearns and Young 1977). At certain levels of concentration, heavy metals can be lethal or have adverse effects at lesser concentrations. Sublethal concentrations of copper produced substantial kidney and gonad damage in sea scallops, whereas cadmium induced hormonal changes such as early gonad maturation (Gould et al. 1985).

Natural deposits of mercury are know to occur in marine bottom sediments. The levels of mercury in Norton Sound (Nelson et al. 1975) exceed the 3.7 ug/l set by the EPA Marine Quality Standards as the maximum allowable concentration. Wood (1974) demonstrated that mercury available to the aquatic environment in any form can result in steady-state concentrations of methyl, dimethyl, and metallic mercury through microbial catalysis and chemical equilibrium. Large-scale gold dredging projects in eastern Norton Sound will result in the discharge and resuspension of sediments that could introduce mercury to the water column.

Marine Mining

Potential impacts include: removal of substrates that serve as habitat for fish and invertebrates; creation (or conversion) of habitats to less productive or uninhabitable sites such as anoxic holes or silt bottom; burial of productive habitats in the vicinity of the mine site or in near shore disposal sites (as in beach nourishment); release of harmful or toxic materials either in association with actual mining, or in connection with machinery and materials used for mining; creation of harmful turbidity levels; adverse modification of hydrologic conditions so as to cause erosion of desirable habitats.

Mining activity, such the extraction of gravel and gold in the Bering Sea, and placer mining spread throughout the state, can lead to the direct loss of EFH for certain species. Gravel is obtained by mining gravel beaches along the Bristol Bay coast (e.g., Goodnews Bay, Kangirlvar Bay) and in the lower reaches of the Yukon and Kuskokwim Rivers. Mining of large quantities of beach gravel can significantly affect the removal, transport, and deposition of sand and gravel along shore, both at the mining site and down current. During mining, water turbidity increases and the resuspension of organic materials could affect less motile organisms (i.e., eggs and recently hatched larvae) in the area. Benthic habitats could be damaged or destroyed by these actions. Neither the future extent of this activity nor the effects of such mortality on the abundance of marine species is known.

Dredging for gold has been attempted at various sites along the Aleutians and the world's largest mechanical dredge was operated offshore near the city of Nome. A similar proposal, which has received all of the necessary permits to proceed, will entail dredging 21,000 acres of sea bottom in Norton Sound for the purpose of recovering gold. Such activity has the potential to cause physical damage directly and indirectly to benthic habitat, juvenile fish, and adult life stages.

Mining practices that can impact EFH include physical and chemical impacts from intertidal dredging and chemicals such as flocculates. However, tailings and discharge waters from settling ponds can result in loss of EFH and life stages of managed species. Placer mining can introduce levels of heavy metals and arsenic that are naturally found within the stream bed sediments. The impact degrades the water quality and levels can become high enough to prove lethal.

The number of individual mining operations for a given area must be monitored. For instance, three mining operations in an intertidal area could impact EFH, whereas one may not. Also, disturbance of previously contaminated mining areas threaten an additional loss of EFH.

Fish Processing Waste - Shoreside and Vessel Operation

Potential impacts include: direct and/or non-point source discharge of nutrients, chemicals, fish by-products, and stick water; overburdening of original habitats; particle suspension.

Discharge of fish waste from shoreside and vessel processing has occurred in marine waters since the 1800's. The discharge can cause water quality problems. Although all fish waste is biodegradable, including heads, viscera, and bones, fish parts that are ground to fine particles may remain suspended for some time. Also, "stick water,"a byproduct of processing fish meal, takes the form of a fine gel or slime which can concentrate on surface waters and move onshore to cover intertidal areas. Crab and fish have been processed for years in various Alaskan ports including Kodiak, Dutch Harbor, St. Paul, and Akutan, with little impact on habitat for crab and other species. However, localized damage to benthic environment consisting of up to several acres of bottom being driven anoxic by rotting processing waste and piles of waste up to 26 feet deep have been recorded. Processors discharging fish waste are required to have National Pollutant Discharge Elimination System (NPDES) permits from the Environmental

Protection Agency. At-sea floating processors are covered by a general NPDES permit which requires that processing waste be ground into finer than one-half inch particles and discharged below the surface.[2]

Although seafood has been processed at sea by foreign fishing vessels in the past without apparent harm to the marine habitat, there has been one instance reported of unusual quantities of fish carcasses (not ground in conformance with the general NPDES permit) accompanied by dead scallops brought up in scallop dredges (Capt. Louie Audet, F/V Shayline Nicholas). It will be important to be alert to similar possible perturbations of the environment resulting from at-sea processing discharges.

Over time, suspended particles will accumulate. Juvenile and adult stages of flatfish are drawn to these areas for food sources. One effect of this attraction may lead to increased predation on juvenile fish species by other flatfishes, diving seabirds, and marine mammals drawn to the food source. However, due to the difficulty in monitoring these outfalls, impacts to species can go undetected.

Fish waste disposal at marinas can also degrade water quality where large numbers of fish are landed and cleaned, or where fish landings are limited but water circulation is poor (USEPA 1993). In sufficient quantity, fish waste disposal can cause dissolved oxygen depression, contamination, and odor problems in coastal waters (USEPA 1993).

Timber Harvest

Potential impacts include: increase in bedload suspended sediments and turbidity from construction of logging roads, in-water stream crossings, exposed slope erosion, removal of streamside vegetation; alter streamflow; introduce excessive nutrients, decrease large woody debris; increase streambank erosion; alter temperature, and have toxic effects on biota.

Forest road construction can destabilize slopes and increase erosion and sedimentation. This erosion occurs in two forms, as mass soil movement (i.e., landslides) and as surface erosion. Both types can introduce debris and sediment into adjacent streams for many years after initial construction. Erosion is most severe where poor construction practices are allowed, inadequate attention is paid to proper road drainage, and where construction occurs in inclement weather. After construction, unpaved logging roads can be a chronic source of sediment to streams. Juvenile salmon avoid habitat areas with suspended sediment (Bisson and Bilby 1982)

Stream crossings by forest roads may block fish migration. Culverts are often installed as an economical alternative to bridges, although bridges are usually less disruptive to the stream environment. Culverts are a serious threat to salmon unless specifically designed, installed, and maintained to accommodate fish passage.

Removal of streamside vegetation during timber harvest activities increases solar radiation to the stream and results in warmer water during summer, especially in small streams. The magnitude of temperature change depends on the amount of timber harvested adjacent to the stream (Meehan et al, 1969; Brown and Krygier, 1970) and time for regrowth of riparian areas. In Southeast Alaska, Meehan et al., (1969) found that maximum temperature in logged streams exceeded those of unlogged control streams by up to 5ºC, but the temperature did not reach lethal levels. The increased water temperature, however, frequently exceeded the optimum for pink and chum salmon documented by Reiser and Bjornn (1979).

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[2] Pers. comm., Dr. Bruce Duncan, U.S. Environmental Protection Agency, 701 C Street, Box 19, Anchorage, AK 99513)

High summer air temperature has been associated with adult salmon mortality. The Alaska Department of Fish and Game compiled a list of 43 streams that had mortality of pink and chum salmon in 1977 associated with high water temperature and low flow. The largest clear-cut in Alaska is located in the Staney Creek watershed. In 1979, 15,000 pink salmon died there before spawning, a result of warm water and low oxygen. In northern areas, the removal of riparian vegetation may cause lower stream temperature during winter, increasing the formation of frazil and anchor ice.

By removing vegetation, timber harvest temporarily reduces transpiration losses from the watershed, thereby elevating water content of soil and increasing run-off during base-flow periods. The elevated water content can reduce soil strength and destabilize slopes, causing increased sediment and debris inputs to streams (Swanston 1974). Sediment deposition in streams can reduce benthic community production (Culp and Davies, 1983) and can cause mortality of incubating salmon eggs and alevins, and habitat loss for juvenile salmon (Heifetz et al. 1996). Cumulative sedimentation from logging activities can significantly reduce the egg-to-fry survival of coho and chum salmon (Cederholm et al. 1981; Cederholm and reid 1987; Hartman et al. 1987). Where egg-to-fry survival is impaired by habitat deterioration escapement goals may have to be increased to offset the effect of decreased spawning success.

Converting large portions of old-growth forests to rapidly growing second-growth forests can permanently reduce summer stream flows and thus permanently reduce salmonid production (Myren and Ellis, 1984). The studies of streams in second-growth forests have demonstrated that the input of large, potentially stable debris (logs and stumps) into salmon habitat from second-growth is reduced relative to inputs from old growth stands (Bisson et al. 1987). Further, the initial high productivity of prey organisms in streams running through open canopy (clear-cut) is short-lived and eventually the quantity of food organisms declines as the canopy closes (Sedell and Swanson, 1984).

Non-point Source Pollution and Urbanization

Potential impacts: direct and/or non-point source discharge of fill, nutrients, chemicals, cooling water, air emissions, and surface and ground waters into streams, rivers, estuaries and ocean waters; conversion of wetlands to sites for residential and related purposes such as roads, bridges, parking lots, commercial facilities; elevation in inorganic and organic nutrient loading in estuarine and coastal waters; coastal development effects to adjacent and downstream ecosystems through modification of the hydrology, chemistry, and biology of streams, lakes, bays, estuaries, and the associated wetlands; and cumulative and synergistic effects caused by association of these and other developmental and non-developmental related activities.

People are moving to the coasts in increasing numbers. A major factor in the threat posed by urban and suburban development is that of non-point source (NPS) discharges of the chemicals used in day to day activities, in operating and maintaining homes and business, for maintaining roads, and for fueling vehicles. Sustainable coastal development from a fishery habitat perspective will need to combine responsible developmental practices at the local and state levels with scientific oversight of environmental conditions in the coastal zone. This can only be accomplished through long-term ecological research and education programs that allow assessment of the combined impacts of exploiting fishery stocks and habitat degradation. The results of such investigations should be used to inform the public and elected officials of the economic and social importance of healthy and productive coastal fishery habitats.

Coastal regions can experience substantial change due to rapid population growth and urbanization. Major point source and non-point source discharges have been linked to industrial/municipal facilities, abandoned hazardous waste sites, and runoff from agriculture and urbanization.   Regional monitoring studies in South Carolina that measured chemical contaminants in surface waters, sediments, and biota indicated linkage between elevated levels of chemical contaminants including polycyclic aromatic hydrocarbons (PAHs) from roadways and marinas and chlordane from housing (Scott et al 1996). Similarly a correlation between elevated levels of coliform bacteria in coastal waters and urbanization was demonstrated (Scott et al 1996).

A consequence of increased human populations is an elevation in inorganic and organic nutrient loading in estuarine and coastal waters. This process can result in transient increased productivity and standing crop of phytoplankton, decreased levels of dissolved oxygen, and shifts in species composition. Higher phytoplankton production and biomass, although potentially beneficial as a food source, may cause decreases in light penetration needed for production by benthic algae, submerged aquatic vegetation and, subsequently, benthic animals. Increased nutrients also can lead to shifts in the species composition of the phytoplankton community where fewer and less desirable organisms may become prevalent. Significant depletion of dissolved oxygen has been shown to occur in association with large algal blooms and significant fish kills have been linked to this process. Nutrient loading has also been linked to noxious algal and dinoflagellate blooms that produce toxins which may be harmful to aquatic organisms and humans. Nutrient loading of scallop populations can cause low dissolved oxygen (hypoxic) conditions (Sindermann 1979), and an increase in bacterial infections (Liebovitz et al. 1984), or algal (Wassman and Ramus 1973) and dinoflagellate blooms (Shumway 1990), all of which can be detrimental to their population.

Urbanization and associated coastal development can effect adjacent and downstream ecosystems through modification of the hydrology, chemistry, and biology of streams, lakes, bays, estuaries, and the associated wetlands. Those aquatic features provide many essential ecological functions including flood and erosion control, diverse biological productivity, and as buffers to physicochemical changes in associated water bodies. Prior to the 1960s, most untreated organic and industrial wastes were dumped directly into streams, lakes or estuaries. Environmental damage from such uncontrolled waste discharge was evident from fish kills, oxygen depletion, massive blooms of nuisance algae, and public health problems. Pacific salmon were most evidently affected by pollution from raw sewage, pulp mill effluents, and acid and metal wastes. Strict regulation of point source discharges of municipal and industrial waste continue to improve that situation. Some toxins from previous unregulated discharges, however, remain trapped in bottom sediments and can be disturbed by current activities.
In urban areas, wetlands are easily degraded or lost by dredging, filling, diking, or draining to provide harbors and building sites. When wetlands are filled, their function of buffering physicochemical changes in adjacent and downstream water bodies is often lost. Development activities can, therefore, have severe impacts on anadromous fish, as well as other wetland-dependant species. Wetlands stabilize hydrology, improve water quality, and increase biological diversity in anadromous fish habitat. Wetlands store and control runoff, thereby decreasing flood peaks and erosion and providing greater base flows in downstream areas. With highly variable runoff, anadromous fish habitat may be eroded during floods and left dry during periods of low runoff. Salmon may be prevented from migrating due to velocity barriers or low water. Spawning areas may be scoured during high water or dry up or freeze during low water. Rearing salmon may be flushed into poor habitat during freshets or trapped in drying areas at low flows. Wetlands can improve water quality as nutrients and pollutants are removed through biological and chemical processes.

Point Source Pollution

Potential impacts include; overburdening of bottom habitat near the location of outfall; degradation; degradation of water quality and habitat from storm water and industrial discharges; pollution effects that may be related to changes in water flow, PH, hardness, dissolved oxygen, and other parameters that affect individuals, populations, and communities; atmospheric pollution dispersal and mixing.

Point source discharges from municipal sewage treatment facilities or storm water discharges are controlled through U.S. Environmental Protection Agency mandated regulations under the Clean Water Act and by state water quality regulations. The primary concerns associated with municipal point source discharges involve treatment levels needed to attain acceptable nutrient inputs and overloading of treatment systems due to rapid development of the coastal zone. Small quantities of industrial and household pollutants have the potential to become large impacts. Storm drains are contaminated from communities with settling and storage ponds, street runoff, harbor activities, and honey buckets. Sewage outfall lines also can significantly alter ph levels of saline waters.

Industrial wastewater effluent is regulated by the U.S. Environmental Protection Agency through the National Pollutant Discharge Elimination System (NPDES) permitting program. This program provides for issuance of waste discharge permits as a means of identifying, defining, and controlling virtually all point source discharges. The complexity and the magnitude of effort required to administer the NPDES permit program limit overview of the program and federal agencies such as the NMFS and the Fish and Wildlife Service generally do not provide comments on NPDES permit notices. For these same reasons, it is not possible to presently estimate the singular, combined, and synergistic effects of industrial (and domestic) discharges on aquatic ecosystems.

At certain concentrations, point source discharges can alter the following properties of ecosystems and associated communities: diversity, nutrient and energy transfer, productivity, biomass, density, stability, connectivity, and species richness and evenness (Carins 1980). At certain concentrations, point source discharges may alter the following characteristics of finfish, shellfish, and related organisms: growth, visual acuity, swimming speed, equilibrium, feeding rate, response time to stimuli, predation rate, photosynthetic rate, spawning seasons, migration routes, and resistance to disease and parasites. In addition to direct effects on plant and animal physiology, pollution effects may be related to changes in water flow, PH, hardness, dissolved oxygen, and other parameters that affect individuals, populations, and communities (Carins 1980). Sewage, fertilizers, and de-icing chemicals (e.g., glycols, urea) are examples of common urban pollutants that decompose with high biological or chemical oxygen demand. Zones of low dissolved oxygen from their decomposition can retard growth of salmon eggs, larvae, and juveniles and may delay or block smolt and adult migration. Sewage and fertilizers also introduce nutrients into urban drainages that drive algal and bacterial blooms which may smother incubating salmon or produce toxins as they grow and die. Thermal effluents from industrial sites and removal of riparian vegetation from streambanks allowing solar warming of water can degrade salmon habitat. Heavy metals, petroleum hydrocarbons, chlorinated hydrocarbons, and other chemical wastes can be toxic to salmonids and their food, and they can inhibit salmon movement and habitat use in streams. Mining, ore processing, smelting, and refining operations often produce heavy metals as waste products that may effect the movement of salmon, causing migration delays. Petrochemicals and chlorinated compounds, such as those in herbicides and pesticides, are toxic or have long-term effects on survival, stamina, and reproduction in salmonids. Peripheral effects of pollution may include forcing rearing fish into areas of high predation or less than optimal salinity for growth.

Contaminants that are emitted into the atmosphere by incinerators, fossil fueled power plants, automobiles, and industry may be transported various distances and directly and indirectly deposited into aquatic ecosystems (Baker et al 1993). As such, the regulation of surface water contamination from atmospheric pollution may require local, regional, and international efforts. Atmospheric linkage of pollutants from local, regional, and remote sources is also possible and, accordingly, the types and levels of contaminants reaching surface waters may vary. Although the magnitude and effect of atmospheric pollution dispersal and mixing may be difficult to assess, it is clear that atmospheric contaminants are routinely deposited in coastal and estuarine waters.

Hazardous Material / General Litter

Potential impacts include: introduction of hazardous and toxic materials from at sea ocean disposal; disposal of contaminated dredged material; illegal dumping of trash, wastewater, and unwanted cargo; accidental disposal of material; "short dumping" of dredged material before permitted disposal area; introduction of general litter such as plastics, derelict fishing gear, and miscellaneous detrital matter.

Under provisions of the Marine Protection Research and Sanctuaries Act (MPRSA), ocean disposal of hazardous and toxic materials, other than dredged materials, is prohibited by U.S. flag vessels and by all vessels operating in the U.S. territorial sea and contiguous zone. The U.S. Environmental Protection Agency (EPA) may issue emergency permits for industrial waste dumping into ocean waters if an unacceptable human health risk exists and no other alternative is feasible. The MPRSA assigns responsibility the ocean disposal of dredged material to the EPA and the U.S. Army Corps of Engineers (COE). This involves: designating ocean sites for disposal of dredged material; issuing permits for the transportation and disposal of the dredged material; regulating times, rates, and methods of disposal and the quantity and type of dredged material that may be disposed of; developing and implementing effective monitoring programs for the sites; and evaluating the effect of dredged material disposed at the sites.

Dumping of trash, wastewater, and unwanted cargo is more likely to occur on the open seas since it is less observable here than in inshore waters. Prior to passage of the Marine Plastic Pollution Research and Control Act (MPPRCA) of 1987 (PL 100-220) an estimated 14 billion pounds of garbage was being dumped into the ocean each year. Of this amount more than 85 percent was believed to have come from the world's shipping fleet in the form of cargo associated wastes.

In the absence of MPRSA and MPPRCA repeal or weakening, major dumping threats to EFH within federal waters should theoretically be limited mostly to illegal dumping and accidental disposal of material in unapproved locations. In reality, the present era of reduced government action and involvement many agencies lack sufficient staff and funds to carry out mandated responsibilities and the opportunity for unobserved illegal and accidental dumping may be substantial. This includes disposal of all types of materials as well as "short dumping" of dredged material whereby dumping takes place between the dredge site and the designated dump site.

The Act to Prevent Pollution from Ships (MARPOL ANNEX V) places limitations on ships to prohibit discharging or depositing any refuse matter, hazardous substance, oil, plastics and dunnage and will lessen impacts to EFH. Persistent plastic debris is introduced into the marine environment from offshore vessels and commercial fisheries, as well as from general shore activities. Debris includes synthetic netting, pots, longline gear, packing bands, and rope. Estimates of debris have been based on observations of debris at sea and on beaches, and occasional reports of accidental or deliberate discards of fishing gear. Studies by Merrell (1984) and others have shown that much of the observed entanglement debris consists of fragments of trawl web. Some trawl web gets discarded overboard following net repair, but most probably gets lost during normal fishing operations (e.g., fishing over rough bottoms, foul weather). Deliberate discharge at sea of all plastics are now prohibited by MARPOL Annex V.

Debris discarded at sea can entangle or be ingested by marine mammals, fish, shellfish, sea birds, and sea turtles. The persistent nature of plastics can pose a hazard to marine life for years. Other lost or discarded gear, such as crab pots continue to fish indefinitely. Neither the extent of debris-related mortality nor population effects on various species are known.

Mariculture and Introduction of exotic species

Potential impacts include: introduction of genetic variance into juvenile and adult populations from hatchery fish stocks; transfer and introduction of exotic and harmful organisms through ballast water discharge.

Mariculture can have adverse effects on habitat because of over-enrichment of water and benthic habitat by uneaten food, feces, or other organic materials (Faris 1987). Accumulations on the bottom can create anaerobic conditions near mariculture sites and degrade foraging areas for juvenile salmon (Phillips et al. 1985). Additional threats include introductions of exotic species or domestic strains which might prey upon, compete with, or interbreed with wild stocks, and the spread of disease from culture facilities. Habitat can also be affected from the development of ancillary facilities, such as access roads, floating processing plants, or caretaker residences.

With recent introduction of the zebra mussel into the Great Lakes and its rapid dispersal into other waters considerable attention is being directed at the introduction of exotic species into U.S. waters via discharge of ship's ballast. According to one estimate (Carlton, 1985) two million gallons of foreign ballast water are released every hour into U.S. waters -- possibly representing the largest volume of foreign organisms released on a daily basis into north American ecosystems. The introduction of exotic organisms threatens native biodiversity and could lead to changes in relative abundances of species and individuals that are of ecological and economic importance. The social and economic implications of zebra mussel introduction into North American waters and the introduction of the comb jelly *Mnemiopsis* into the Sea of Azov in Russia -- which has helped decimate the region's anchovy fishery -- point out the seriousness of this threat.

Oil and Natural Gas Activities

Potential impacts include: elimination or damage to bottom habitat due to drill holes and positioning of structures such as drilling platforms, pipelines, anchors, etc;, release of harmful and toxic substances from extracted muds, oil, and gas; and from materials used in oil and gas recovery; damage to organisms and habitats due to accidental spills; damage to fishing gear due to entanglement with structures and debris; and damage to fishery resources and habitats due to effects of blasting (used in platform support removal); and indirect and secondary impacts to near shore aquatic environments affected by product receiving, processing, and distribution facilities.

Information can be found in Berg (1977); Deis (1984); OCSEAP Synthesis Reports on the St. George Basin (1982), the Navarin Basin (1984), and the North Aleutian Shelf (1984); Thorsteinson and Thorsteinson (1982); and the University of Aberdeen (1978). The Alaska offshore area comprises 74 percent of the total area of the U.S. continental shelf. Because of its size, the Alaska outer continental shelf (OCS) is divided into three subregions—Arctic, Bering Sea, and Gulf of Alaska. Areas where oil and gas leases have occurred or are scheduled in the BSAI area include the Navarin Basin (1989)(Morris, 1981), St. George Basin (1990)(NMFS, 1979), North Aleutian Basin (1990)(NMFS, 1980) and the Shumagin Basin (1992) (Morris, 1987).

If a commercial quantity of petroleum is found, its production would require construction of facilities and all the necessary infrastructure from pipelines to onshore storage and shipment terminals or for building offshore loading facilities. It is believed that Bering Sea oil would be pipelined to shore and then loaded on tankers for transportation from Alaska. In the Navarin Basin, however, offshore-loading terminals may be more feasible. Unlike exploration, production would continue year-round and would have to surmount the problems imposed by winter sea-ice in many areas. Norton Basin and perhaps Navarin

Basin would require ice-breaking tanker capabilities. There are also occasional proposals for tankering oil from Arctic fields via the Bering Sea, which would also require ice-breaking capabilities.

Oil and gas related activities have the potential to cause pollution of habitats, loss of resources, and use conflicts. Physical alterations in the quality and quantity of existing local habitats may occur because of the siting and construction of offshore drilling rigs and platforms, loading platforms, or pipelines.

Accidental discharge of oil can occur during almost any stage of exploration, development, or production on the OCS or in near shore base areas. Oil spills may result from many possible causes including equipment malfunction, ship collisions, pipeline breaks, human error, or severe storms. Oil spills may also be attributed to support activities associated with product recovery and transportation. In addition to crude oil spills, chemical, diesel, and other oil-product spills can occur in association with OCS activities. Of the various potential OCS-related spill sources, the great majority are associated with product transportation activities (USDOI, MMS, 1996).

The 1989 *Exxon Valdez* oil spill in Prince William Sound, the largest oil spill ever in U.S. waters, contaminated 2,000 km of coastal habitat (Spies et al. 1996). It spilled 42 million liters of crude oil which had immediate acute effects and longer-term impacts on fish and wildlife. Beached oil penetrated deeply into cobbled beaches and still persists in some areas beneath the surface layer of rocks and under mussel beds. Contamination of intertidal spawning areas for pink salmon caused increased embryo mortality and possible long-term developmental and genetic damage (Bue et al. in press). Wild pink salmon spawn in intertidal stream deltas, and therefore, are susceptible to marine oil spills. The embryo is a critical stage of salmon development and is vulnerable to pollution because of its long incubation in intertidal gravel and its large lipid-rich yolk which will accumulate petroleum hydrocarbons from low-level, intermittent exposures (Heintz et al., unpub.).

Residual oil from a spill can remain toxic for long periods because the most toxic components are the most persistent. Petroleum is a complex mixture of alkanes and aromatic hydrocarbons, of which the alkyl-substituted and multi-ring polynuclear aromatic hydrocarbons (PAH) are the most toxic and persistent. These large PAH predominate in weathered oil. Because of low solubility in water, the large PAH probably contribute little to acute toxicity of oil-water solutions. Lipophilic PAH, however, may cause physiological injury if they accumulate in tissues after lengthy exposure (Heintz et al., unpub.).

Chronic small oil spills are also a potential problem because residual oil can build up in sediments and affect living marine resources. Low levels of PAH from such chronic pollution can be accumulated in salmon tissues and cause lethal and sublethal effects, particularly at the embryo stage. Demonstrated effects from low-level chronic exposure include increased embryo mortality, reduced marine growth, and increased straying in returning adults.

Many factors determine the degree of damage from an oil spill. The most important variables are the type of oil, size and duration of the spill, geographic location, season, and oceanographic conditions. Habitats most sensitive to oil pollution are typically located in coastal areas with low physical energy (e.g., estuaries, tidal marshes). Exposed rocky shores and ocean surface waters are high-energy environments where physical processes more rapidly remove spilled oil. Benthic and scallop species can also be affected by oil spills, via decreased gill respiration, but the effects are considered to be sort lived (Gould and Fowler 1991). Spiny scallops were found to be moderately sensitive to acute exposures (96 hour) to Cook Inlet crude and No. 2 oil (Rice et al. 1979).

After a large spill, aromatic hydrocarbons would generally be at toxic levels to some organisms within this slick. Beneath and surrounding the surface slick, there would be some oil-contaminated waters.

Vertical mixing and current dispersal acts to reduce the oil concentrations with depth and distance. If the oil spill trajectory moves toward land, habitats and species could be affected by the loading of oil into contained areas of the near shore environment. In the shallower waters, an oil spill could be mixed by wave action throughout the water column and contaminate subtidal sediment. Suspended sediment can also act to carry oil to the seabed. In the *Exxon Valdez* oil spill, 13% of spilled oil was deposited in subtidal sediments where it was available to deposit-feeding organisms (Spies et al. 1996).

Oil mixed into bottom sediments persists for years and becomes a long term source of low level pollution. Cold temperature slows the evaporation biodegradation processes, so toxic hydrocarbons persist longer. Oil can also be trapped by ice. Toxic aromatic fractions mixed to depth under the surface slick could cause mortalities and sublethal effects on salmon.

Tainting of salmon and fishing gear flesh is a potential problem in areas subject to either chronic or acute oil pollution. The *Exxon Valdez* oil spill, for example, caused the closure of fisheries for black cod, shrimp, herring,
and salmon. Although sockeye salmon were not directly affected by the spill, the fishery in upper Cook Inlet was closed to forestall fouling of gear and public perception of tainting. The sockeye fishery closure caused over-escapement to some freshwater spawning and rearing lakes and subsequent poor production of fry and smolts.

Large oil spills are the most serious potential source of oil and gas development-related pollution. Offshore oil and gas development will inevitably result in some oil entering the environment. Most spills are expected to be of small size, although there is a potential for large spills to occur. Chronic oil spills which build up in the sediments around rigs and facilities are also a problem. In whatever quantities, lost oil can affect habitats and living marine resources. Many factors determine the degree of damage from a spill; the most important variables are the type of oil, size and duration of the spill, geographic location of the spill, and the season. Although oil is toxic to all marine organisms at high concentrations, certain species are more sensitive than others. In general, the early life stages (eggs and larvae) are most sensitive; juveniles are less sensitive, and adults least so (Rice, et al. 1984).

Habitats most sensitive to oil pollution are typically located in those coastal areas with the lowest physical energy because once oiled, these areas are the slowest to repurify. Examples of low energy environments include tidal marshes, lagoons, and seafloor sediments. Exposed rocky shores and ocean surface waters are higher energy environments where physical processes will more rapidly remove or actively weather spilled oil.

It is possible for a major oil spill (i.e., 50,000 bbls) to produce a surface slick covering up to several hundred square kilometers of surface area. Oil would generally be at toxic levels to some organisms within this slick.. Beneath and surrounding the surface slick, there would be some oil-contaminated waters. Mixing and current dispersal would act to reduce the oil concentrations with depth and distance. If the oil spill trajectory moves toward land, habitats and species could be affected by the loading of oil into contained areas of the near shore environment. In the shallower waters, an oil spill could be mixed throughout the water column and contaminate the seabed sediments. Suspended sediment can also act to carry oil to the seabed. It is believed up to 70 percent of spilled oil may be incorporated in seafloor sediments where it is available to deposit feeding organisms (crab) and their prey items.

Toxic fractions of oil mixed to depth and under the surface slick could cause mortalities and sublethal effects to individuals and populations. However, the area contaminated would appear negligible in relation to the overall size of the area. For example, Thorsteinson and Thorsteinson (1982) calculated that a 50,000 barrel spill in the St. George Basin would impact less than 0.002 percent of the total size of this area. Even if concentrations of oil are sufficiently diluted not to be physically damaging to marine organisms or their consumers, it still could be detected by them, and alter certain behavior patterns. If an oil spill reaches near shore areas with productive nursery grounds or areas containing high densities of fish eggs and larvae, a year class of a commercially important species of fish or shellfish could possibly be reduced, and any fishery dependent on it may be affected in later years. An oil spill at an especially important habitat (e.g., a gyre where larvae are concentrated) could also result in disproportionately high losses of the resource compared to other areas. Additional concern is the unknown impact of an oil related event near and/or within ice. The water column adjacent to the ice edge is stable. This stabilization (or stratification) would allow relatively quick transport of oil to the seafloor. Additionally, oil trapped in ice could impact habitat significantly after the initial event, months or years later, and even into a different region or country.

Other sources of potential habitat degradation and pollution from oil and gas activities include the disposal of drilling muds, fluids, and cuttings to the water and seabed, and dredged materials from pipeline laying or facilities construction. Naturally occurring sediments or introduced materials may contain heavy metals or other chemical compounds that would be released to the environment, but the quantities are generally low and only local impacts would be expected to occur.

Areas that are currently and historically influenced by oil and gas production operation facilities: Arctic Ocean/ North Slope, Chukchi Sea, Bering Sea/Navarin Basin, Gulf of Alaska/Yakutat Basin, Cook Inlet, and Prince William Sound.

Hydroelectric Projects, Dams and Impoundments

Potential impacts include: detrimental effects on salmon and their habitat; transformation of a river from its natural free-flowing state to an impoundment fundamentally alters that environment; decline or loss of original species; change in temperature regime; change in circulation and flow patterns.

Dams are a significant barrier to upstream and downstream migrations of salmon, and have probably caused the greatest loss of salmon habitat due to human activities in the lower 48 states. Dependence on technology to provide passage around dams has seldom been successful. Fishway design and flow are important to attract and guide adult salmon into passage facilities. Poorly designed fishways can inhibit upstream movement of adults, causing migration delays, increased pre-spawning mortality, and reduced reproductive success in fish that eventually reach their spawning grounds (U.S. Bureau of Reclamation 1985; Hallock et al. 1982). Dams also present obstacles to downstream passage of juveniles, and passage through turbines or over spillways can result in migration delays, increase predation, and direct mortality.

Major adverse effects on salmon stocks and habitat caused by dams have been avoided or mitigated in Alaska, as managers have learned from mistakes made in the lower 48 states. A more complete discussion of effects of dams on salmon can be found in the Habitat Appendix of the Eighth Amendment to the Fishery Management Plan for Commercial and Recreational Salmon Fisheries off the Coasts of Washington, Oregon, and California Commencing in 1978 (PFMC 1987).

Existing Federal Energy and Regulatory Commission (FERC) hydroelectric projects within Alaska include (Name Project #): Beaver Falls (# 01922), Black Bear Lake (#10440), Blind Slough (#00201), Blue Lake (# 02230), Bradley Lake (#08221), Burnett River Hatchery (#10773), Chignik (# 00620), Cooper Lake (#02170), Dry Spruce (# 01432), Goat Lake (# 11077), Green Lake (#02818), Humpback Creek (#08889), Jetty Lake (#03017), Ketchikan Lakes (#00420), Pelican (#10198), Power Creek (#11243), Salmon Creek (#02307), Skagway-Dewey Lakes (#01051), Solomon Gulch (# 02742), Swan

Lake (#02911), Terror Lake (#02743), Tyee Lake (#03015). Recent interests for new projects include: Twin Lake and Old Harbor on Kodiak Island; Silver Lake and Power Creek in Prince William Sound.

FERC projects can have concerns regarding upstream and downstream passage; provision of adequate instream flow regimes for spawning, rearing, and migration; maintenance of water quality for anadromous fish. Each of these areas is discussed below.

Fish passage for both upstream and downstream migrating salmon, steelhead, and other anadromous fish must be provided to avoid delay, injury, and excessive stress. Required passage facilities must be installed during project construction and must be operated at all times that fish are present. In order to satisfy these objectives, it is necessary to develop a proposal for fish passage facilities. The proposal should define type, location, size, method of operation, and other pertinent facility characteristics. It should reflect state and federal fisheries agency input and design criteria.

Upstream passage facilities are generally required at any project feature which impairs natural passage conditions. At some projects this may require a fish collection system with fishway entrances correctly located and adequate attraction flows, a fish ladder, and an exit structure to return adults to the stream at an appropriate location upstream from the project. At other projects, less extensive facilities are required depending upon the degree of passage obstruction and other site-specific characteristics.

For downstream migrating juveniles, the basic need is to screen turbine intakes to prevent the fish mortalities associated with passage through the turbines by excluding fish from the intake flow. Requirements concerning screen areas and mesh sizes must be satisfied to assure acceptable operation. A bypass flow to safely carry fish from in front of the screens to an appropriate location below the project is a fundamental need. Frequently a system of ports and bypass pipes is necessary. Passage facilities must be designed and maintained to function properly through the full range of flows normally occurring during fish migration periods.

Construction impacts include: siltation of spawning gravels; timing; temperature elevation or reduction which may cause reduced fish growth or disease; gas super-saturation which may occur due to plunging water and result in fish gas-bubble disease; reservoirs which tend to be nutrient traps may cause decreased fish production downstream by reducing available food supplies; silt-laden reservoir releases which decrease invertebrate production and salmon egg survival.

Construction and operation of the project without fishery considerations could result in an interruption/diversion of water supply to and degradation of water quality. The interruption/diversion could be in terms of destruction of incubating eggs, alevins, and fry in the system. Disrupted flows and/or water quality could also result in alteration of migration and spawning habitat. Construction of the dam, powerhouse, and penstock structures could increase turbidities downstream with potential impacts to migration, spawning and rearing of salmon. Construction of the dam, powerhouse, and penstock structures could also result in erosion and increased input of particulate matter into the creek with adverse impacts to migration, spawning, incubation, and rearing salmon.
Adequate flow regimes and water quality are critical for anadromous fish. Consequently, flow regimes and water quality sufficient for successful spawning, incubation, rearing, and migration must be established and maintained through and downstream of project area where needed. If flow reduction, diversion, or modification of flow regimes are anticipated in the operation scenario for the project, anadromous fisheries could be adversely affected not only in the immediate project area but in the entire system downstream of the facility. Examples of this include the diversion of water from the creek/river

to a powerhouse which results in a decrease of water which reaches downstream spawning gravel and rearing habitat and tailrace water discharges that could attract and divert returning adult fish from creek/river, thereby decreasing egg deposition and jeopardizing future returns. To address these matters, flow studies must be performed to determine flow regimes that will conserve and protect stocks of anadromous fish in the river system.

Marine Traffic and Transportation

Potential impacts include: potentially harmful vessel operations activities include, but are not limited to: discharge or spillage of fuel, oil, grease, paints, solvents, trash, wastes (including sanitary discharges), and cargo into coastal and tributary waters; alteration of aquatic habitats by the operation of marinas, piers, and docks; disturbance and damage to living marine resources and their habitats by waves, noise, propellers, water jets and other vessel related operations such as anchoring and grounding; exacerbation of shoreline erosion due to wakes.

Routine vessel traffic, discharges, and accidents are potential threats to EFH. The Far East Trade Route takes vessels north by northwest out of the Straits of Juan De Fuca, across the North Pacific and Gulf of Alaska, then through Unimak Pass, Alaska en route to the Far East. Cargo, bunker sea, tanker, freighter, fishing, and recreational vessels make up the vast fleet that transit these waters. In recent times, the freighter vessel Swallow, tanker vessel Exxon Valdez, and freighter vessel Kiroshima grounded and the resulting oil spills proved lethal to marine life and ecosystems. Oil tug and barge traffic is common and their route transits to the major fueling ports of Unalaska, St. Paul, and other coastal cities. In addition, summer vessel traffic increases in the offshore waters with tug and tow traffic bound for the North Slope developments. Other increased traffic seasons coincide with commercial fishery openings, which usually end with at least one vessel grounding or sinking. EFH loss from hazardous cargo is ever present. Other direct impacts from vessels include pollutants such as raw sewage, bilge oil discharge, plastics, and food wastes.

The chronic effects of vessel grounding, prop scarring, and anchor damage are generally more problematic in conjunction with recreational vessels. While grounding of ships and barges is less frequent, individual incidents can have significant localized effects.

Marinas and other sites where vessels are moored are often plagued by accumulation of anti-fouling paints in bottom sediments, by fuel spillage, and overboard disposal of trash and wastewater. A study of marinas found that they may contribute to increases in fecal coliforms, sediment oxygen demand, and chlorophyll a, and decreases in dissolved oxygen.(NC Department of Environment, Health, and Natural Resources 1990)

In the Coastal Zone Management Act of 1972, as amended, Congress declared it to be national policy that state coastal management programs provide for public access to the coasts for recreational purposes. Clearly, boating and adjunct activities (e.g., marinas) are an important means of public access. When these facilities are poorly planned or managed, however, they may pose a threat to the health of aquatic systems and may pose other environmental hazards (USEPA 1993). Since marinas are located at the water's edge, there is often no buffering of the release of pollutants to waterways. The USEPA (1993) identifies the following adverse environmental impacts as possibly being related to marinas and associated activities:

(1) Pollutants discharged from boats;
(2) Pollutants generated from boat maintenance activities on land and in the water;
(3) Exacerbation of existing poor water quality conditions;

(4) Pollutants transported in storm water runoff from parking lots, roofs, and other impervious surfaces; and
(5) The physical alteration or destruction of wetlands and of shellfish and other bottom communities during the construction of marinas, ramps, and related facilities.

Marina related impacts to aquatic systems include lowered dissolved oxygen, increased temperature, bioaccumulation of pollutants by organisms, water contamination, sediment contamination, resuspension of sediments, loss of SAV and estuarine vegetation, change in photosynthesis activity, change in the nature and type of sediment, loss of benthic organisms, eutrophication, change in circulation patterns, shoaling and shoreline erosion. Pollutants that result from marinas include nutrients, metals, petroleum hydrocarbons, pathogens, and polychlorinated biphenyls (USEPA 1993).

Marina personnel and boat owners use a variety of boat cleaners, such as teak cleaners, fiberglass polish, and detergents and cleaning boats over the water, or on adjacent upland, creates a high probability that some cleaners and other chemicals will entering the water (USEPA 1993). Copper-based antifouling paint is released into marina waters when boat bottoms are cleaned in the water (USEPA 1993). Tributyl-tin, which was a major environmental concern, has been largely banned except for use on military vessels. Fuel and oil are often released into waters during fueling operations and through bilge pumping. Oil and grease are commonly found in bilge water, especially in vessels with inboard engines, and these products may be discharged during vessel pump out (USEPA 1993).

Boats propellers can also impact fish and fish habitat by direct damage to multiple life stages of associated organisms, including egg, larvae, juveniles, and through water column de-stratification (temperature and density), resuspending sediments, and increasing turbidity (Stolpe 1997; Goldsborough 1997).

Grounding tends to be an infrequent occurrence on fishery habitats such as seagrass beds and coral reefs. The degree of damage is related to the size of the grounded vessel. Large vessels that ground in shallow water seagrass beds may cause considerable localized damage especially when propeller force is used break free. Crushing damage is usually minimal. Grounding on coral reefs may cause extensive to the reef structure since most coral is highly susceptible to breakage and crushing, and recovery is slow.

One of the most conspicuous byproducts of boating activity and human occupation of coastal environments is the presence of marine debris or trash in the coastal waters, beaches, intertidal flats, and vegetated wetlands. The debris ranges in size from microscopic plastic particles (Carpenter et al. 1972), to mile-long pieces of drift net, discarded plastic bottles, bags, aluminum cans, etc.

Sewage and other wastes discharged from recreational boats may be most problematic in marinas and anchorage sites where vessels are concentrated. Despite existing federal and state regulations involving discharges of sewage and other materials, detection and control of related activities is difficult and some discharges still occur. According to the 1989 American Red Cross Boating Survey, there were approximately 19 million recreational boats in the United States (USEPA 1993). About 95 percent of these boats were less than 26 feet in length and a large number of these boats used a portable toilet, rather than a larger holding tank. Given the large percentage of smaller boats, facilities for the dumping of portable toilet waste should be provided at marinas that service significant numbers of boats under 26 feet in length (USEPA 1993).

Increased recreational boating activity may contribute significantly to pollution of coastal waters by petroleum products. All two-cycle outboard engines require that oil be mixed with gasoline, either directly in the tank or by injection. That portion of the oil that does not burn is then ejected, along with other exhaust products, into the water.

Natural Adverse Impacts

Potential impacts include potential threats from geophysical and seismic activity such as volcanoes, earthquakes, shelf vents; natural occurring elements such as oil seeps and coal outcrops; coastal and inland storms can cause severe acute and chronic perturbations including habitat erosion, burial by deposition of sediment on deepwater habitats and wetlands; creation of strong currents that alter habitats and remove biota; damage by wind and waves; elevation of turbidity that can cause physiological damage and disrupt feeding, spawning migration, and other vital processes; and abrupt changes in salinity and other water quality characteristics such as fecal coliform levels. Changes in marine habitat may also be the result of the activities of marine animals.

Long-term climatological changes can bring about similar changes by altering weather patters. Large scale ecological changes may also occur where temperature changes favor or harm a particular species or group. Changes that cause relocation of frontal boundaries, weed lines, and stratification and temperature boundaries may also cause substantial and undesirable environmental change These events potentially can eliminate EFH for any species without any indication or warning. Impacts range from alteration of habitat from undersea landslides to introduction of exotic prey species following a favorable current. Events as such can be theorized but hard to foresee and manage.

Ocean-atmospheric physics is hypothesized to cause variation in recruitment of several crab stocks in the North Pacific Ocean and Bering Sea with the decadal shifts in barometric pressure indices, sea level, sea surface temperature and ecosystem conditions (Zeng and Kruse, MS). In years of strong Aleutian Lows, warm incubation temperatures promote crab egg hatching too early to match the spring bloom reducing survival of first feeding larvae. A strong Aleutian Low also promotes a more diverse assemblage of species in the phytoplankton community and adversely effects larvae of red king crab. Wind stress causing advection of very specific stocks of crab larvae may also be important to the crab recruitment process.

The activities of some marine animals also alter benthic habitat. California grey whales "till the soil" when feeding on amphipods. In the Chirikof Basin and the area south of St. Lawrence Island, gray whales created pits averaging 2.5 meters long, 1.5 meters wide, and 10 centemeters deep. Creation of these pites are estimated to suspend 172 million metric tons of sediment a year -- three times the amount of suspended sediment discharged annually by the Yukon River (Nelson and Johnson 1987). Pacific walrus make furrows (averaging 47 meters long, 0.4 meters wide, and 0.1 meters deep) in the benthic habitat while searching for clams and are estimated to disturb around 100 million metric tons of sediment per year (Nelson and Johnson 1987; Sease and Chapman 1988).   Sea otters, by preying on sea urchins, allow kelp beds to increase which increases siltation rates reducing habitat for barnacles, mussels, sea stars and hermit crabs (Palmisano and Estes 1977). Sun stars *(Pycuopodia helianthoides*) using their suckers like conveyor belts are able to dig holes up to 12 inches deep in their search for clams (Mauzen et al. 1968).

Although the issue of global warming is controversial, all models predict some temperature increases, especially in the higher latitudes of the Northern Hemisphere (USDC 1997). According to the U.S. Department of Commerce, significant Arctic warming, particularly after 1920, may be related to increased solar radiation, increased volcanic activity, and other naturally occurring factors (USDC 1997a). Human induced increases in greenhouse gas concentrations combined with natural conditions to cause unprecedented warming in the Arctic in the 20th century and between 1840 and the mid-20th century the Arctic warmed to the highest level in the past four centuries.

Global temperature increases of a degree or two can cause sea level rise if melting of permafrost and ice cap follow. Possible effects include: significant loss of coral reefs, salt marshes, and mangrove swamps that are unable to keep up with sea level rise; loss of species whose temperature tolerance ranges are exceeded (this could be especially problematic for corals); elevated nutrient and sediment loading due to Tundra run-off; saltwater intrusion into freshwater ecosystems such as freshwater marshes and forested wetlands; invasion of warmer water species into areas occupied by cooler habitat species; and physical changes in the Arctic Seas that could have much broader implications by altering flows, food chains, and climate (USDC 1997). The severity of impact on natural resources, including certain essential fish habitat will be determined by natural and human obstruction to inland habitat shifts, resilience of species and populations to withstand changes in environmental conditions, and the rate of environmental change (USDC 1997a).

See table of contents for the following table:

Table 9.1 Summary of non-fishing adverse impacts to essential fish habitat.

9.1.3 Habitat Conservation and Enhancement Recommendations

Habitat alteration may lower both the quantity and quality of species production through physical changes or chemical contamination of habitat. Species and individuals within species differ in their tolerance to effects of habitat alteration. It is possible for the timing of a major alteration event and the occurrence of a large concentration of living marine resources to coincide in a manner that may affect fishery stocks and their supporting habitats. The effects of such events may be masked by natural phenomena or may be delayed in becoming evident. However, the process of habitat degradation more characteristically begins with small-scale projects that result in only minor losses or temporary disruptions to organisms and habitat. As the number and rate of occurrence of these and other major projects increases, their cumulative and synergistic effects become apparent over larger areas. It is often difficult to separate the effects of habitat alteration from other factors such as fishing mortality, predation, and natural environmental fluctuations. Decreasing the probability of impact will lead to the highest protection of EFH. The probability of impact directly relates to the amount human activity we introduce to an environment. The following recommendations are offered to protect EFH.

Near Shore Habitat and Waters (0-3nm)

Recommendation	Area	Species
Minimize construction of structures such as causeways or breaches that would affect local flushing, water temperatures, water quality, lateral drift, and/or migration.	Sensitive areas, special aquatic and vegetation areas	groundfish, salmon, scallop, crab
Minimize construction of structures such as docks that ground on tidal lands during low water events.	Sensitive areas, special aquatic and vegetation areas	groundfish, salmon, crab
Minimize deposition of fill in tidelands.	Sensitive areas, special aquatic and vegetation areas	groundfish, salmon, crab
Stage rapid response equipment and establish measures for accidental impacts such as oil and hazardous material spills.	ports, sensitive areas	groundfish, salmon, scallop, crab
Monitor point source pollution sites such as fish processing waste, sewage, and storm water run off outfalls.	ports, vessel processors, communities	groundfish, salmon, scallop, crab
Minimize disposal or dumping of dredge spoils, drilling muds, and municipal and industrial wastes.	known concentration of bottom species and their habitats	groundfish, salmon, scallop, crab
Test dredge spoils prior to marine disposal	port and upland sources	groundfish, salmon, scallop, crab
Establish monitoring that incorporates Federal and State regulatory agency determinations, i.e., tracking database and GIS system	area wide	groundfish, salmon, scallop, crab

Pelagic Habitat and Waters (3-12nm)

Recommendation	Area	Species
Assess cumulative oil and gas production activities.	BSAI, Chukchi Sea, OCS, Cook Inlet, GOA	groundfish, salmon, scallop, crab
Identify marine disposal sites.	area wide	groundfish, salmon, scallop, crab
Establish monitoring that incorporates Federal and State regulatory agency determinations, i.e., tracking database and GIS system	area wide	groundfish, salmon, scallop, crab
Establish no discharge zones for ballast waters to prevent introduction of non-indigenous species and chemical contaminants.	ports, known gyres areas	groundfish, salmon, scallop, crab
Minimize disposal or dumping of dredge spoils, drilling muds, and municipal and industrial wastes.	known concentration of bottom species and their habitats	groundfish, salmon, scallop, crab

Offshore Habitat and Waters (>12 nm)

Recommendation	Area	Species
Establish monitoring that incorporates Federal and State regulatory agency determinations, i.e., tracking database and GIS system	area wide	groundfish, salmon, scallop, crab
Establish no discharge zones for ballast waters to prevent introduction of non-indigenous species and chemical contaminants.	known offshore gyre areas	groundfish, salmon, scallop, crab
Minimize disposal or dumping of dredge spoils, drilling muds, and municipal and industrial wastes.	known concentration of bottom species and their habitats	groundfish, salmon, scallop, crab

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9.2 Identification of Fishing Activities Affecting EFH

Adverse effects from fishing activities may include physical, chemical, or biological alterations of the substrate, and loss of, or injury to, benthic organisms, prey species and their habitat, and other components of the ecosystem. FMPs must include management measures that minimize adverse effects on EFH from fishing, to the extent practicable, and identify conservation and enhancement measures. The FMP must contain an assessment of the potential adverse effects of all fishing activities used in waters described as EFH. This assessment should consider the relative impacts, compared to natural impacts and cycles, of all fishing equipment types used in EFH on different types of habitat found within EFH. Special consideration should be given to equipment types that will affect habitat areas of particular concern. In completing this assessment, Councils should use the best scientific information available, as well as other appropriate information sources, as available. Included in this assessment should be consideration of the establishment of research closure areas and other measures to evaluate the impact of any fishing activity that physically alters EFH.

Councils must act to prevent, mitigate, or minimize any adverse effects from fishing, to the extent practicable, if there is evidence that a fishing practice is having an identifiable adverse effect on EFH. In determining whether it is practicable to minimize an adverse effect from fishing, Councils should consider whether, and to what extent, the fishing activity is adversely impacting EFH, including the fishery; the nature and extent of the adverse effect on EFH; and whether the management measures are practicable, taking into consideration the long and short-term costs as well as benefits to the fishery and its EFH, along with other appropriate factors, consistent with national standard 7.

Fishery management options may include, but are not limited to:

> Fishing equipment restrictions. These options may include, but are not limited to: Seasonal and areal restrictions on the use of specified equipment; equipment modifications to allow escapement of particular species or particular life stages (e.g., juveniles); prohibitions on the use of explosives and chemicals; prohibitions on anchoring or setting equipment in sensitive areas; and prohibitions on fishing activities that cause significant physical damage in EFH.
>
> Time/area closures. These actions may include, but are not limited to: Closing areas to all fishing or specific equipment types during spawning, migration, foraging, and nursery activities; and designating zones for use as marine protected areas to limit adverse effects of fishing practices on certain vulnerable or rare areas/species/life history stages, such as those areas designated as habitat areas of particular concern.
>
> Harvest limits. These actions may include, but are not limited to, limits on the take of species that provide structural habitat for other species assemblages or communities, and limits on the take of prey species.

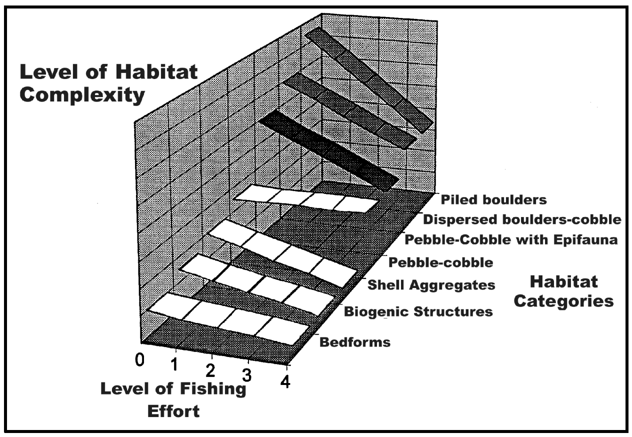
9.2.1 Literature Review on the Effects of Fishing Gear on Habitat

Two literature reviews on the effects of fishing gear on habitat are included in this section. The first is an executive summary of a paper written by Dr. Peter Auster and Dr. Richard Langton called "The Indirect Effects of Fishing". This paper was contracted to the authors by NMFS, through the American Fisheries Society, specifically to address the impact of fishing on EFH. The paper summarizes and interprets the scientific literature on the effects of fishing on structural components of habitat, infaunal and epifaunal communities, and ecosystem processes. Copies of the Auster and Langton (1998) paper are available from the NMFS. The second paper included in this section was written by Ivan Vining, David Witherell, and Jon Heifetz, entitled "The Effects of Fishing Gear on Benthic Communities". Their paper is a literature review of scientific studies on the effects of different gear types. The paper was originally prepared for the NPFMC's 1998 Ecosystems Considerations chapter of the annual stock assessment documents, and is included here in its entirety. Copies are available from the Council office.

9.2.1.1 The Indirect Effects of Fishing: An Executive Summary

A paper entitled "The Indirect Effects of Fishing" was prepared by Peter Auster and Richard Langton under contract from the American Fisheries Society. The paper summarizes and reviews the current literature on fishing impacts as they relate to EFH. A first draft was released for peer review on January 2, 1998 and a final draft released in April, 1998. Interested persons may obtain this paper and other cited documents from the Council office.

The paper discusses the studies within four broad subject areas: effects of gear on non-landed target species, effects on structural components of habitat, effects on benthic community structure, and effects on ecosystem level processes. Although a vast majority of the scientific studies on gear impacts have focused on trawl gear, the authors have attempted to analyze the impacts of habitat disturbance, rather than focus on the impacts of each gear type on habitat. Towards that end, the authors have developed a conceptual model to assist managers with understanding how fishing gear could impact different habitats. The adjacent figure illustrates this. In very complex habitats, such as piled boulders or cobble with epifauna (corals, bryozoans, anenemones, etc.), even relatively low levels of fishing effort can drastically alter the habitat. On more simple habitats, such as bedforms (such as sand or silt bottoms), fishing has a relatively minor effect on the habitat complexity. An abstract of the Auster and Langton paper is provided below.



Conceptual model of how fishing could differentially affect habitat depending on its complexity.

Abstract

The Sustainable Fisheries Act of 1996 mandates that regional fishery management Councils designate essential fish habitat (EFH) for each of the species which are managed, assess the effects of fishing on EFH, and develop conservation measures for EFH where needed. This synthesis of effects of fishing on fish habitat was produced to aid the fishery management councils in assessing the impacts of fishing activities. A wide range of studies were reviewed that reported effects of fishing on habitat (i.e., structural habitat components, community structure, and ecosystem processes) for a diversity of habitats and fishing gear types. Commonalities of all studies included immediate effects on species composition and diversity and a reduction in habitat complexity. Studies of acute effects were found to be a good

predictor of chronic effects. Recovery after fishing was more variable, depending on habitat type, life history strategy of component species, and the natural disturbance regime. The ultimate goal of gear impact studies should not be to retrospectively analyze environmental impacts but ultimately to develop the ability to predict outcomes of particular management regimes. Synthesizing the results of these studies into predictive numerical models is not currently possible. However, conceptual models are presented which coalesce the patterns found over the range of observations. Conceptual models can be used to predict effects of gear impacts within the framework of current ecological theory. Initially, it is useful to consider fishes' use of habitats along a gradient of habitat complexity and environmental variability. A model is presented of gear impacts on a range of seafloor types and is based on changes in the structural habitat values. Disturbance theory provides the framework for predicting effects of habitat change based on spatial patterns of disturbance. Alternative community state models, and type 1-type 2 disturbance patterns, may be used to predict the general outcome of habitat management. Primary data are lacking on the spatial extent of fishing induced disturbance, the effects of specific gear types along a gradient of fishing effort, and the linkages between habitat characteristics and the population dynamics of fishes. Adaptive and precautionary management practices will therefore be required until empirical data becomes available for validating model predictions.

9.2.1.2 The Effects of Fishing Gear on Benthic Communities

Portions of the following section have been excerpted from the following paper:
Vining, I., D. Witherell, and J. Heifetz. 1997. The effects of fishing gear on benthic communities. p.13-25. Ecosystem Considerations for 1998. North Pacific Fishery Management Council, Anchorage, Alaska.

In recent years, there has been a growing awareness and concern about the effects of resource extraction on ecosystems. Fishery managers around the world are beginning to incorporate, or at a minimum acknowledge, the effects of fishing on marine ecosystems. The groundfish fisheries in Alaska are no exception. Concern has been expressed by scientists, conservationists, fishermen, and others about potential negative effects of fishing gear on bottom habitat, particularly with regard to habitat alteration. In this chapter, we provide a review of scientific studies done to date on the effects of fishing gear on benthic communities of the Gulf of Alaska, Bering Sea, and Aleutian Islands areas.

Fisheries in the North Pacific are numerous and utilize different gear types. The fisheries and associated gear for the Bering Sea/Aleutian Islands (BSAI) and Gulf of Alaska fisheries (GOA) are listed in the adjacent table. Federal regulation § 679.2 specifies the following authorized gear types: dive, fixed gear, hook-and-line, jig, longline, longline pot, non-pelagic trawl, pelagic trawl, pot-and-line, scallop dredge, and troll gear. In this section, we summarize potential effects only for primary gears used in the groundfish, scallop, and crab fisheries.

Fishing Gear used in the North Pacific, by fishery.

FMP	Fishery	Gear
BSAI and GOA	groundfish	trawl, longline, jig, pot
BSAI and GOA	halibut	longline, hook&line, troll, jig
BSAI and GOA	scallop	dredge
BSAI	crab	pot
BSAI and GOA (State managed)	salmon	gill net, seine, troll line, fish wheels, or spears
non-FMP (State)	herring	trawl, seine, gill net, pound net
non-FMP (State)	shrimp	pots, trawls
non-FMP (State)	razor clam	shovel, fork
non-FMP (State)	sea urchin	handpicking, aided by diving gear or abalone iron
non-FMP (State)	octopus	pot
non-FMP (State)	abalone	diving gear and abalone iron
non-FMP (State)	sea cucumber	handpicking, aided by diving gear

If the gear, habitat, and communities were homogeneous, studies designed to measure the effect of fishing on benthic communities would be much simpler. However, there is heterogeneity in all aspects of fishing, as well as the habitat and communities affected by fishing gear. When studying gear effect, many questions need to be answered, such as: Do all gears have similar effects? How much actual damage is being done? How long will the damage last? How will damage be measured? Does the extent and longevity of damage depend on bottom type? Does the fishing affect all organisms in the community equally? The purpose of this section of the Ecosystems Chapter is to review the completed work or the work in progress to answer some of these questions, and summarize conclusions. A summary of literature used for this paper is provided in Table 1.

Trawl Gear

Concerns over the effects of trawling are not new, nor limited to the North Pacific. Trawling was an issue, as early as 1350, when it was banned in the United Kingdom to protect fry of fish (de Groot 1984). Since 1938, studies have been conducted on the east coast of Canada and United States, to evaluate possible effects of trawling on the benthic communities (Ketchen 1947; Graham 1955; Messieh et al. 1991). There has also been an extensive investigation in the North Sea by the Netherlands Institute for Sea Research evaluating the effects of beam-trawl fisheries on the bottom fauna (BEON-RAPPORT 8 1990; Bergman and Hup 1992). The effects of trawling are also being studied in New Zealand and Australia, with special attention being paid to hard-bottom trawling (Hutchings 1990; Jones 1992).

There are people who considered the negative effect of trawl gear “common sense” and “intuitive,” and have written articles pointing to likely ways the gear is having a negative effect on the environment (Apollonio 1989; McAllister 1991; Russel 1997). The scientific community, in general, also tends to accept that trawling alters the bottom habitat (Auster et al. 1996). The root of the problem and the cause of controversy lies in the definition of “negative effect” and the degree of change in the benthic habitat or communities before the change is “destructive.”

The otter trawl is the principle gear used in bottom trawl fisheries in the GOA and BSAI, and advancements in fishing gear and vessel technology have made gear more efficient. These advances mean that heavier nets are dragging over seabeds, and possibly altering the sea-floor more than was observed in earlier studies. Also, larger ships, with greater horsepower and larger, stronger nets are exploring and fishing areas not previously available to the industry (Auster et al. 1996). A further consideration is the domestication of the groundfish industry in the GOA and BS since the Magnuson Act of 1976, which changed the character of trawling in Alaska from large foreign factory vessels to a mixture of a domestic catcher-processors and numerous smaller catcher vessels.

Physical effects of trawling include plowing and scraping the sea-floor, resuspension of sediment, and lowering of habitat complexity. Plowing and scraping effects depend on towing speed, substrate type, strength of tides and currents, and gear configuration (Jones 1992). It has been found that otter doors tend to penetrate the substrate 1 cm - 30 cm; 1 cm on sand and rock substrates, and 30 cm in some mud substrates (Krost et al. 1990; Jones 1992; Brylinsky et al. 1994). Another factor which will cause variation in the depth of the troughs made by the otter doors is the size (weight) of the doors, i.e., the heavier the doors the deeper the trough (Jones 1992). These benthic troughs can last as little as a few hours or days in mud and sand sediments, over which there is strong tide or current action (Caddy 1973; Jones 1992), or they can last much longer, from between a few months to over 5 years, in seabeds with a mud or sandy-mud substrate at depths greater than 100 m, with weak or no current flow (Krost et al. 1990; Jones 1992; Brylinsky et al. 1994).

Another aspect of plowing and scraping is the alteration done by the footrope. Once again, different types of footropes will cause more or less alteration. Those footropes which are designed to roll over the sea-floor (the type generally on soft bottoms, employed in the GOA and BS), cause little physical alteration, other than smoothing the substrate and minor compression (Brylinsky et al. 1994; Kaiser and Spencer 1996). However, since a trawler may re-trawl the same area several times, these minor compressions can cause a “packing” of the substrate (Schwinghammer et al. 1996). Further compression of the substrate can occur as the net becomes full and is dragged along the bottom.

The trawling of an area can cause resuspension of both inorganic and organic sediments. Churchill (1989) found that trawling can be a significant contributor to the time-averaged suspended sediment load over heavily trawled areas, especially at depths where bottom stress due to tidal and current action is generally weak. In the GOA, there is relatively weak current and tidal action near the sea-floor over much of the groundfish fishing grounds, with a variety of seabed types such as gravely-sand, silty-mud, and muddy to sandy gravel, as well as areas of hard-rock (Hampton et al. 1986). The BS has relatively weak currents, on the other hand, with relatively strong tidal action (currents) accounting for up to 95% of all flow as deep as 200 m, with principally gravely-sand and silty-sand seabed (National Research Council 1996).

The reduction in habitat complexity can be examined in two broad categories: (1) small localized changes, and (2) larger area changes. The small localized changes refer to the smoothing of patchy biogenic depressions and movement of boulders (Auster et al. 1996). The broader area changes refer to the general reductions in habitat complexity with increases in trawling activity (Auster et al. 1996; Schwinghammer et al. 1996).

Mortality can be incurred to those organisms incidentally captured (bycatch), and discarded back into the sea. The mortality rate of the bycatch depends on the species, age and size of a species, the type of gear, the time and type of shipboard handling, and the size of the haul, along with ocean and atmospheric conditions (Hill and Wassenberg 1990; Stevens 1990; Fonds 1991). It is difficult to generalize the fate of bycaught benthic organisms returned to the sea or compare results from different studies on this subject. In addition, studies have only focused on the survival of fish and crab discards.

Several studies have examined the mortality of crabs taken as bycatch in North Pacific trawl fisheries. In one study, a standard sole trawl (with roller gear) in a subarctic area (Bering Sea) caught king and Tanner crabs while fishing for sole, sorted the catch with the time on deck being between .5-1.5 hours, then placed the crabs in holding tanks for 48 hours; the resulting mortality rate was 79% for king crab and 78% for Tanner crab (Stevens, 1990). Blackburn and Schmidt (1988) made observations on instantaneous mortality of crab taken by domestic trawl fisheries in the Kodiak area. They found mortality for soft-shell red king crab averaged 21%, hard-shelled red king crab 1.2%, and 12.6% for Tanner crab. Another trawl study indicated that trawl induced instantaneous mortalities aboard ship were 12% for Tanner crab and 19% for red king crab (Owen 1988). Fukuhara and Worlund (1973) observed an overall Tanner crab mortality of 60-70% in the foreign Bering Sea trawl fisheries. They also noted that mortality was higher in the summer (95%) than in the spring (50%). Hayes (1973) found that mortality of Tanner crab captured by trawl gear was due to time out of water, with 50% mortality after 12 hours. Natural Resource Consultants (1988) reported that overall survival of red king crab and Tanner crab bycaught and held in circulation tanks for 24-48 hours was <22%. In analyses of groundfish plan amendments, the estimated mortality rate of trawl bycaught red king crab and Tanner crab was assumed to be 80% (NPFMC 1993).

Damage or mortality of benthic organisms can occur due to the passage of the trawl over the seabed without actually catching the organisms. Non-retained organisms may be subject to mortality from contact with trawl doors, bridles, footrope, or trawl mesh, as well as exposure to silt clouds produced by trawl gear. Mortality of fish escaping from trawl codends may range from none to 100%, and may depend on numerous factors, including fish species, tow size and duration, the size and type of mesh used (Sangster 1992). Mortality can occur due to contusions, a build-up of lactic acid, scale loss and mucus removal, and skin damage due to abrasion and collision with net walls (Sangster 1992; Chopin and Arimoto 1995).

Studies of fish escapement mortality have exhibited a wide range of results. Very low escapement mortality was observed for Alaskan pollock under experimental conditions (Efanov and Istomin 1988). Main and Sangster (1988) observed that mortality of haddock passing through a diamond mesh codend exhibited delayed mortality: 33% mortality after 11 days and 82% mortality after 108 days. DeAlteris and Reifsteck (1993) observed escapement mortality of scup (Stenotomus chrysops) to be 0% to 50%, and less than 4% for winter flounder (Plueronectes americanus) tested by an experimental codend. Bergman et al. (1989) studied the mortality of fishes escaping from commercial beam trawls, and observed mortalities of dab (Limanda limanda), plaice, and sole totaled 44%, 15%, and 0%, respectively, after being held in a cage for 24 hours. Van Beek et al. (1989) also studied the mortality of sole escaping from beam trawls, and their results indicated that 40% of the sole died after escaping through the meshes. Mortality of herring (Clupea harengus) escaping from trawl codends can be higher than for groundfish. Suuronen et al. (1992) observed mortality of codend escapees to be very high (85-90%), with most deaths occurring 3-8 days after escape. Another study of herring showed lower mortality (3-30%) for herring escaping from codends (Efanov 1981).

Besides direct mortality from being caught and handled, there will be further mortality due to relocation into unsuitable habitat and predation while returning to the sea floor. This type of mortality will also depend on many conditions such as depth, type of species, age and size of species, predator concentration and oceanic conditions. Although there are few studies which have considered these sources of mortality, neither relocation nor predation will likely result in 100% mortality (Hill and Wassenberg, 1990).

Similar to the mortality of bycatch, the survival of benthic organisms in the path of the trawl will depend on several factors. The mortality rate will depend on the species, species age and size, the type of gear, the size of the haul, substrate morphology, and ocean conditions. The most severe damage done to benthic organisms by otter trawls is from the trawl doors, especially sedentary organisms that live in the upper 5 cm of the seabed (Rumohr and Krost, 1991). Rumohr and Krost (1991) further found that thin-shelled bivalves such as *Syndosmya alba*, *Mya* sp. and *Macoma calcarea*, as well as starfish sustain heavy damage due to the trawl doors, whereas thick-shelled bivalves such as *Astarte borealis* and *Corbula gibba* were less likely to be damaged. In one another experiment, hard-shelled red king crab were tethered in the path of an Aleutian combination trawl (Donaldson 1990). Only 2.6% of the crabs that were interacted with the trawl, but not retained, were injured, suggesting a low mortality rate. Other organisms found to be affected by the passage of trawls and specifically the trawl doors are diatoms, nematodes and polychaetes (Brylinsky et al. 1994).

The immediate effect of trawling on hard-bottom seabeds can be intense in certain vulnerable habitats. It was found that from a single tow using roller gear, 3.9% of the octocorals and 30.4% of the stony coral were damaged, as well as 31.7% of the sponges (van Dolah et al., 1987). A similar study in Florida found that 80% of the stony coral and 38% of the soft corals were damaged, as well as 50% of the sponges. However, the trawls in this study were a ridged roller gear assemblage (Tilmant 1979). Both of these studies were in sub-tropical areas. No studies were found assessing trawling in temperate or subarctic hard-bottom habitat, however current work on this is being carried out in the GOA (Heifetz 1997).

Although mortality from bycatch or trawl passage appears to be fairly high for various organisms, some studies have found recolonization can occur over a relatively short time period. Nematodes and polychaetes returned to their pre-trawled levels in less than 7 weeks and diatoms increased in abundance in trawl troughs within 80 days (Brylinsky et al., 1994). Small epibenthic species that have been resuspended can recover to pre-trawl densities in 24 hours (Rumohr and Krost, 1991). The sponges and most of the corals damaged in the hard-bottom studies, returned to their pre-study levels in approximately a year.

One of the principle concerns associated with trawling is the potential effects on benthic organisms that fish depend on for food. At least in the short term, prey items immediately available to fish do not appear to be reduced. Caddy (1973) found that fish and crabs were attracted to the trawl path, presumably to feed on exposed or dead benthos, within 1 hour after fishing. Other studies have also observed increases in scavenging in the wake of beam-trawls (Kaiser and Spencer 1994; Kaiser and Spencer 1996a). Furthermore, the densities of some of the species examined in the study, were 30 times greater than outside the trawl tracks. In Kiel Bay (Baltic Sea), it was believed that cod fed extensively on Arctica islandica which were crushed or broken by trawl doors (Rumohr and Krost 1991; Jones 1992).

Minor short-term changes in individual species distribution are not likely to greatly affect the entire ecosystem, excessively. The ecosystem is in a constant flux, with many natural phenomena making changes to the environment (de Groot 1984; Brylinsky et al. 1994). The specific question is whether fishing causes long-term changes (negative) in the benthic community structure.

There have been changes to benthic communities from trawling due to habitat alteration. The trawl doors may be the most damaging to benthic organisms on a short-term basis. However, even in deep areas where the troughs may be recognized after long periods (5 years), the doors do not likely have an excessive long- term effect on the overall area, because the relatively small trough is between 0.2 - 2 m (Krost et al. 1990; Rumohr and Krost 1991; Brylinsky et al. 1994). The greater long-term damage to the habitat may be caused by the net and footrope due to their much larger width at 3-166 m (1.5-90 fathoms), with many between 20-50 m (Grahm 1955).[3] The smoothing caused by multiple trawls (as discussed earlier) removes patchy biogenic depressions and moves boulders, both of which are extremely important habitat to juvenile fish and crustaceans (Armstrong et al. 1993; Auster et al. 1996). Multiple trawls in an area also pack down and lower the complexity of the substrate which will likely reduce the exchange capacity and lead to less species diversity (Jones 1992; Kaiser and Spencer 1996b; Schwinghamer et al. 1996). Some studies have concluded that trawling tends to favor fast-growing, fast-reproducing and relatively short-lived (r-selected) species, such as polychaetes, at the expense of slow-growing, slow-reproducing and relatively long-lived (k-selected) species such as crustaceans (Reise 1982; de Groot 1984; Kaiser and Spencer 1996b).

Sediment resuspension, as discussed above, has an effect on the benthic communities as well. Increased sediment suspension can cause reduction of light levels on the seabed, smother benthos following resettlement, create anaerobic conditions near the seabed, and reintroduce toxins that may have settled out of the water column (Churchill 1989; Jones 1992, Messieh et al. 1991).

Dredge Gear

Dredging for scallops may affect habitat by causing unobserved mortality to scallops and other marine life, mortality of discards, and modification of the benthic community and sediments. Similar to trawling, dredging places fine sediments into suspension, bury gravel below the surface and overturn large rocks that are embedded in the substrate (NEFMC 1982, Caddy 1973). Dredging can also result in dislodgement of buried shell material, burying of gravel under resuspended sand, and overturning of larger rocks with an appreciable roughening of the sediment surface (Caddy 1968). A study of scallop dredging in Scotland showed that dredging caused significant physical disturbance to the sediments, as

[3] Pers. comm., Chris Blackburn, Alaska Groundfish Databank, Kodiak, AK.

indicated by furrows and dislodgement of shell fragments and small stones (Eleftheriou and Robertson 1992). The authors note, however, that these changes in bottom topography did not change sediment disposition, sediment size, organic carbon content, or chlorophyll content. Observations of the Icelandic scallop fishery off Norway indicated that dredging changed the bottom substrate from shell-sand to clay with large stones within a 3-year period (Aschan 1991). For some scallop species, it has been demonstrated that dredges may adversely affect substrate required for settlement of young to the bottom (Fonseca et al. 1984; Orensanz 1986). Mayer et al. (1991), investigating the effects of a New Bedford scallop dredge on sedimentology at a site in coastal Maine, found that vertical redistribution of bottom sediments had greater implications than the horizontal translocation associated with scraping and plowing the bottom. The scallop dredge tended to bury surficial metabolizable organic matter below the surface, causing a shift in sediment metabolism away from aerobic respiration that occurred at the sediment-water interface and instead toward subsurface anaerobic respiration by bacteria (Mayer et al. 1991). Dredge marks on the sea floor tend to be short-lived in areas of strong bottom currents, but may persist in low energy environments (Messieh et al. 1991).

Two studies have indicated that intensive scallop dredging may have some direct effects on the benthic community. Eleftheriou and Robertson (1992), conducted an experimental scallop dredging in a small sandy bay in Scotland to assess the effects of scallop dredging on the benthic fauna. They concluded that while dredging on sandy bottom has a limited effect on the physical environment and the smaller infauna, large numbers of the larger infauna (mollusks) and some epifaunal organisms (echinoderms and crustaceans) were killed or damaged after only a few hauls of the dredge. Long-term and cumulative effects were not examined, however. Achan (1991) examined the effects of dredging for islandic scallops on macrobenthos off Norway. Achan found that the faunal biomass declined over a four-year period of heavy dredging. Several species, including urchins, shrimp, seastars, and polychaetes showed an increase in abundance over the time period. In summary, scallop gear like other gear used to harvest living aquatic resources, may effect the benthic community and physical environment relative to the intensity of the fishery.

Several studies have addressed mortality of scallops not captured by dredges. In Australia, this type of fishing gear typically harvests only 5-35% of the scallops in their path, depending on dredge design, target species, bottom type, and other factors (McLoughlin et al. 1991). Of those that come in contact with the dredge but are not captured, some elude the passing dredge and recover completely from the gear interaction. Some injuries may occur during on board handling of undersized scallops that are returned to the sea or during gear interactions on the sea floor (Caddy 1968; Naidu 1988; Caddy 1989), and delayed mortality can result from siltation of body cavities (Naidu 1988) or an increased vulnerability to disease (McLoughlin et al. 1991) and predation (Elner and Jamieson 1979). Caddy (1973) estimated incidental dredge mortality to be 13 to 17%, based on observations of broken and mutilated shells of Atlantic sea scallops. However, a submersible study of sea scallops from the mid-Atlantic indicated that scallop dredges capture with high efficiency those scallops which are within the path of the scallop dredge and cause very low mortality among those scallops that are not captured (NEFMC 1988). Murawski and Serchuk (1989) made submersible observations of dredge tracks and found a much lower mortality rate (<5%) for Atlantic sea scallops. The difference in mortality between these two studies can be attributed to the substrate on which the experiments were conducted. Caddy's work was done in a sandy/gravelly area and Murawski and Serchuk worked on a smooth sand bottom. Shepard and Auster (1991) investigated the effect of different substrate types on dredge induced damage to scallops and found a significantly higher incidental damage on rock than sand, 25.5% versus 7.7%. For weathervane scallops, mortality is likely to be lower as this species prefers smoother bottom substrates consisting of mud, clay, sand, or gravel (Hennick 1970a, 1973).

Atlantic sea scallop beds and the benthic community associated with scallop fishing grounds in the Bay of Fundy were assessed in 1969 (Caddy 1976). During the intervening years, the area has seen great changes in fishing pressure with recent effort amounting to more than 90 vessels of over 25 GRT continuously fishing the grounds with Digby drags for days at a time (Kenchington and Lundy 1991). Since 1969, there have also been dramatic fluctuations in scallop abundance, including both record highs and lows for this century. In particular, scallop abundance rose to over 1000 times “normal” levels with the recruitment of two strong year-classes in 1985 and 1986. This information indicates that extensive dredging does not affect the recruitment of scallops to a productive ground.

Observations from scallop fisheries across the state suggest that mortality of crab bycatch may be lower on average than those taken in trawl fisheries, perhaps due to shorter tow times, shorter exposure times, and lower catch weight and volume. For crab taken as bycatch in the Gulf of Alaska weathervane scallop fishery, Hennick (1973) estimated that about 30% of Tanner crabs and 42% of the red king crabs bycaught in scallop dredges were killed or injured. Hammerstrom and Merrit (1985) estimated mortality of Tanner crab at 8% in Cook Inlet. Kaiser (1986) estimated mortality rates of 19% for Tanner crab and 48% for red king crab bycaught off Kodiak Island. Urban et al. (1994) recorded that in 1992, 13-35% of the Tanner crab bycaught were dead or moribund before being discarded with the highest mortality rate occurring on small (<40 mm carapace width, CW) and large (>120 mm CW) crabs. Delayed mortality of Tanner crab resulting from injury or stress has not estimated. Mortality in the Bering Sea appears to be lower than in the Gulf of Alaska, in part due to different sizes of crab taken. Observations from the 1993 Bering Sea scallop fishery indicated lower bycatch mortality of red king crab (10%), Tanner crab (11%) and snow crab (19%) (Barnhart et al. 1996). As with observations from the Gulf of Alaska, mortality appeared to be related to size, with larger and smaller crabs having higher mortality rates on average than mid-sized crabs (Barnhart et al. 1996). Delayed mortality was not estimated. In one groundfish plan amendment analysis, all sources of crab mortality were examined; in this analysis a 40% discard mortality rate for all crab species was assumed for scallop fisheries (NPFMC 1993).

Adverse effects of scallop dredges on benthic communities in Alaska may be lower in intensity than trawl gear. Studies on effects of trawl and dredge gear have revealed that, in general, the heavier the gear in contact with the seabed, the greater the damage (Jones 1992). Scallop dredges generally weigh less than most trawl doors, and the relative width they occupy is significantly smaller. A 15' wide New Bedford style scallop dredge weighs about 1,900 lbs (Kodiak Fish Co. data). Because scallop vessels generally fish two dredges, the total weight of the gear is 3,800 lbs. Trawl gear can be significantly heavier. An 850 HP vessel pulling a trawl with a 150' sweep may require a pair of doors that weigh about 4,500 pounds. Total weight of all trawl gear, including net, footrope, and mud gear would weigh even more.[4] Hence, based on weight of gear alone, scallop fishing may have less effect than bottom trawling, however its effects may be more concentrated.

Longline Gear

Very little information exists regarding the effects of longlining on benthic habitat. Observations of halibut longline gear made by NMFS scientists during submersible dives off southeast Alaska provide some information (NPFMC 1992). The following is a summary of these observations: “Setline gear often lies slack on the sea-floor and meanders considerably along the bottom. During the retrieval process, the line sweeps the bottom for considerable distances before lifting off the bottom. It snags on whatever objects are in its path, including rocks and corals. Smaller rocks are upended, hard corals are broken, and soft corals appear unaffected by the passing line. Invertebrates and other light weight

[4] Pers. comm., Teresa Kandianis, 2977 Fox Road, Ferndale, WA 98248.

objects are dislodged and pass over or under the line. Fish, notably halibut, frequently moved the groundline numerous feet along the bottom and up into the water column during escape runs disturbing objects in their path. This line motion was noted for distances of 50 feet or more on either side of the hooked fish."

Some crabs are caught incidentally by longline gear in pursuit of groundfish, and a portion of these crabs die. No field or laboratory studies have been made to estimate mortality of crab discarded in longline fisheries. However, based on condition factor information from the trawl survey, mortality of crab bycatch has been estimated and used in previous analyses (NPFMC 1993). Discard mortality rates were estimated at 37% for red king crab and 45% for *C. bairdi* Tanner crab taken in longline fisheries. No observations had been made for snow crab, but mortality rates may be similar to Tanner crab.

Mortality of groundfish discarded in longline fisheries has not been studied extensively in Alaska. Studies with Pacific halibut have shown that discards may have high mortality if not released carefully from hooks. Additionally, some species such as rockfish may not survive changes in pressure when they are hauled up quickly from the bottom. Mortality of discarded halibut has been estimated to be about 15% for most longline fisheries (Williams 1997).

Pot Gear

Pot gear is used in the North Pacific to harvest crabs and groundfish. This gear type likely affects habitat during the process of setting and retrieving pots; however, no research has been conducted to date.

Like other fisheries, pot fisheries incur some bycatch of incidental fish and crab. The groundfish pot fishery targets Pacific cod, but takes other species such as crab and flatfish which are discarded. Mortality of bycaught fish in groundfish pot fisheries has not been studied, with the exception of Pacific halibut. Based on viability data, it has been estimated that mortality of halibut bycaught in groundfish pot fisheries averages about 7% (Williams 1997). Bycatch in crab pot fisheries includes crabs, octopus, Pacific cod, halibut, and other flatfish (Tracy 1994). Crab bycatch includes females of target species, sublegal males of target species, and non-target crab.

There are a variety of effects caused by handling, ranging from sublethal (reduced growth rates, molting probabilities, visual acuity from bright lights, and vigor) to lethal effects. Several laboratory and field studies have been conducted to determine mortality caused by handling juvenile and female crab taken in crab fisheries. Studies have shown a range of mortality due to handling based on gear type, species, molting stage, number of times handled, temperature, and exposure time (Murphy and Kruse 1995). Handling mortality may have contributed to the high natural mortality levels observed for Bristol Bay red king crab in the early 1980s (65% for males and 82% for females) that, along with high harvest rates, resulted in stock collapse (Zheng et al. 1995). However, another study concluded that handling mortality was not responsible for the decline on the red king crab fishery (Zhou and Shirley 1995a). Byersdorfer and Watson (1992, 1993) examined red king crab and Tanner crab taken as bycatch during the 1991 and 1992 red king crab test fisheries. Instantaneous handling mortality of red king crab was <1% in 1991, and 11.2% in 1992. Stevens and MacIntosh (1993) found average overall mortality of 5.2% for red king crabs and 11% for Tanner crabs on one commercial crab vessel. Authors recommend these results be viewed with caution, noting that experimental conditions were marginal. Mortality for red king crab held 48 hours was 8% (Stevens and MacIntosh 1993, as cited in Queirolo et al. 1995). A laboratory study that examined the effects of multiple handling indicated that mortality of discarded red king crabs was negligible (2%), although body damage increased with handling mortality (Zhou and Shirley 1995a). Delayed mortality of crabs due to handling does not appear to be influenced by method of release. In an experiment done during a test fishery, red king crab thrown off the deck while the vessel was moving versus those gently placed back into the ocean showed no differences in tag return rates (Watson and Pengilly 1994). Handling methods on mortality has been shown to be non-significant in laboratory experiments with red king crab (Zhou and Shirley 1995a, 1995b) and Tanner crab (MacIntosh et al. 1995). Although handling did not cause mortality, injury rates were directly related to the number of times handled.

Mortality of crabs is also related to time out of water and air temperature. A study of red king and Tanner crabs found that crabs exposed to air exhibited reduced vigor and righting times, feeding rates (Tanner crabs), and growth (red king crabs) (Carls and Clair 1989). Cold air resulted in leg loss or immediate mortality for Tanner crabs, whereas red king crabs exhibited delayed mortality that occurred during molting. A relationship was developed to predict mortality as the product of temperature and duration of exposure (measured as degree hours). Because BSAI crab fisheries occur during November through February, cold exposure could cause significant handling mortality to crabs not immediately returned to the ocean. However, Zhou and Shirley (1995) observed that average time on deck was generally 2 to 3 minutes, and they concluded that handling mortality was not a significant source of mortality.

Salmon Fishing Gear

Directed fisheries on salmon in Alaska include marine commercial and recreational hook-and-line fisheries; marine commercial gill-net and seine fisheries; and estuarine and riverine gill-net (both set-net and drift), recreational, personal use, and subsistence fisheries. Two types of impacts can occur: (1) direct effects of the fishing gear on habitat; and (2) by-catch or entanglement of non-target species. In the marine fisheries, direct impact of the gear on marine habitats is limited, but some localized effects can occur, such as trolling weights damaging coral or purse seines damaging kelp beds or benthic structure. By-catch and entanglement of non-target species can occur in the marine fisheries, such as by-catch of demersal rockfish in hook-and-line fisheries, and entanglement of seabirds and marine mammals in net fisheries. In the estuarine and riverine fisheries, direct impacts on riparian vegetation and channel morphology can occur from fishing activities, such as damage to the stream bank from boat wakes and removal of woody debris to provide access. Trampling of stream banks and the stream channel can also damage salmon habitat. Where use levels are high, this type of impact may require restoration or management initiatives. An example is the Kenai River where restoration work was needed to repair damage from recreational fishing for chinook salmon and other salmonids.

Summary of the Impacts of Fishing on Habitat

Alterations to natural communities are inevitable when harvesting marine organisms with any gear type. The removal of any organism has , by itself, an effect. It has been suggested that though there is some alteration due to fishing, it is simply a necessity to harvest the resource (de Groot 1984). Furthermore, some studies have shown that the community will return to relatively pristine conditions in a relatively short time period following a fishing closure, if there was an effect at all (Graham 1955; van Dolah et al. 1987; Rumohr and Krost 1991; Jones 1992; Brylinsky et al. 1994). On the other hand, there is also the suggestion that pre-fishing, “pristine” conditions are not known, since almost all study areas have had some form of fishing prior to the study (Auster et al. 1996). Lastly, there are also studies that conclude that trawling, in some situations, may cause long-term changes in habitat and community structure (Auster et al. 1996; Kaiser and Spencer 1996b; Schwinghamer et al. 1996).

To further confuse the issue, nothing is static. The fishing industry makes regular alterations to gear and fishing techniques. The oceanic and atmospheric conditions change continually, on both local and global scales, all of which may affect groundfish or the benthic communities upon which they depend. Lastly, other human induced actions such as pollution, mining and petroleum exploration can affect benthic communities as well. However, declines of some fisheries being observed around the world have served to emphasize that all sources of potential effects should be considered by managers aiming for sustainability.

Table 9.2 Summary of literature cited. Those studies done in Alaska are shown in bold.

Authors	Year	Gear Type	Location	Fishery	Main Emphais of Citation
Apollonio	1989	Otter Trawl	Northwest Atlantic	Groundfish	Habitat and Benthic Alterations
Armstrong, et. al.	**1993**	**Bottom Trawl**	**Bering Sea**	**Groundfish**	**Bycatch**
Auster, et.al.	1996	Otter Trawl	Gulf of Maine	Groundfish	Habitat and Benthic Alterations
BEON-Rapport 8	1990	Beam Trawl	North Sea	Groundfish	Habitat and Benthic Alterations
Bergman and Hup	1992	Beam Trawl	North Sea	Groundfish	Habitat and Benthic Alterations
Bergman, et. al.	1989	Beam Trawl	North Sea	Groundfish	Habitat and Benthic Alterations
Blackburn and Schmidt	**1988**	**Otter Trawl**	**GOA (Kodiak area)**	**Survey**	**Bycatch**
Brylinsky, et. al.	1994	Otter Trawl	Bay of Fundy	Flounder	Habitat and Benthic Alterations
Caddy	1973	Otter Trawl	Gulf of St. Lawrence	Groundfish	Habitat and Benthic Alterations
Churchill	1989	Otter Trawl	Mid-Atlantic Bight	Groundfish	Sediment Resuspension
de Groot	1984	Beam+Otter Trawl	North Sea	Groundfish	Habitat and Benthic Alterations
Efanov and Istomin	1988				Bycatch
Fonds, M.(ed.)	1991	Beam Trawl	North Sea		Bycatch
Fukuhara and Worlund	1973	Otter Trawl	Bering Sea	Groundfish	Bycatch
Gibbs, et. al.	1980	Otter Trawl	New South Wales	Shrimp	Habitat and Benthic Alterations
Graham	1955	Otter Trawl	North Sea	Plaice	Habitat and Benthic Alterations
Heifetz (ed.)	1997	Otter Trawl	BSAI/GOA	Groundfish	Habitat and Benthic Alterations
Hill and Wassenberg	1990	Otter Trawl	South Pacific	Shrimp	Bycatch
Hutchings	1990	Otter Trawl	Australia	Shrimp	Habitat and Benthic Alterations
Jones	1992	Beam +Otter Trawl	World Wide	Multiple	Habitat, Bycatch, Alterations
Kaiser and Spencer	1994				Bycatch
Kaiser and Spencer	1996	Beam Trawl			Bycatch
Kaiser and Spencer	1996	Beam Trawl	Europe Shelf	Groundfish	Habitat and Benthic Alterations
Ketchen	1947	Otter Trawl	Western N. Atlantic	Groundfish	Habitat and Benthic Alterations
Krost, et. al.	1990	Otter Trawl	Western Baltic	Groundfish	Habitat and Benthic Alterations
Main and Sangster	1988	Otter Trawl	North Atlantic	Groundfish	Bycatch
Mayer et.al.	1991	Otter Trawl	Gulf of Maine	Groundfish	Sediment Resuspension
McAllister	1991	Trawls (in general)	World Wide	Groundfish	Habitat and Benthic Alterations
Messieh, et.al.	1991	Otter Trawl	Eastern Canada	Groundfish	Habitat and Benthic Alterations
NRC	**1988**	**Otter Trawl**	**Bering Sea**	**Groundfish**	**Bycatch**
Owen	**1988**	**Otter Trawl**	**GOA(Kodiak area)**	**Survey**	**Bycatch**
Rumohr and Krost	1991	Trawls (in general)	Western Baltic	Groundfish	Habitat and Benthic Alterations
Russell	1997	Trawls (in general)	Georges Bank	Groundfish	Habitat and Benthic Alterations
Sangster	1992				Bycatch
Schwinghamer et.al.	1996	Otter Trawl	Grand Banks	Groundfish	Habitat and Benthic Alterations
Stevens	**1990**	**Otter Trawl**	**Gulf of Alaska**	**Sole**	**Bycatch**
Suuronen et.al.	1993				Bycatch
van Beek et.al.	1989	Otter+Beam Trawls	North Sea	Flatfish	Bycatch
van Dolah et.al.	1987	Roller Trawl	Coast of Georgia	Survey	Habitat and Benthic Alterations
Williams	**1997**	**Otter Trawl**	**BSAI/GOA**	**Groundfish**	**Bycatch**

9.2.2 Current Research on Fishing Gear and Habitat Interactions in the North Pacific

Habitat can be considered as the biotic-abiotic interface. This view is a composite of several terms including habitat (physical locality), ecological niche (environmental conditions), and biotope (location plus environmental conditions suitable for particular species). A few general principles underlie much of habitat (actually *biotope*) research: (1) a single species is not ubiquitous, thus habitat is restrictive; (2) a species is not uniformly distributed throughout its area of occurrence, thus habitat quality varies; and (3) there is significant temporal variability in habitat quality and location. In general, fish abundance reflects habitat quality. Because fish are able to select habitat, the best habitat is occupied first and at the highest density, while marginal areas are eventually occupied in response to crowding . As such, relative abundance is a reasonable first approximation of habitat quality.

Current research includes environmental data collection, habitat characterization, environmental impacts of fishing, and analysis of community ecology. New technology (acoustic bottom typing, laser line systems and GIS) may allow for much improved data collection and analysis. Acoustic bottom typing enables passive collection of sea floor attributes during fishing and/or survey operations. Laser line systems function much like a towed camera system but it is useable in somewhat more turbid conditions. Habitat characterization research has focused on identifying limits and preferences of fish species, incorporating the effects of population size and describing associations with surface sediments. An investigation into the environmental impacts of bottom trawling in the Bering Sea was initiated last year. Comparison of heavily fished and unfished areas in Bristol Bay will assess chronic exposure effects. Experimental trawling in unfished areas in 1997 and beyond will provide information on acute exposure effects and the recovery process will be monitored. These studies will enable resource managers to evaluate the efficacy of time-area closures in soft-bottom areas. Similar studies are being conducted in harder bottom areas of the Gulf of Alaska using a submersible and video assessment technology. Additional planned studies include a retrospective analysis for the Gulf and a field study of trawl impacts in gorgonian coral habitat in the Aleutians. Potential changes in Bering Sea community ecology will be examined by comparing current fish assemblages with those identified in an earlier (1982) study. Habitat research bottlenecks include the limited seasonal coverage of data collection, the general paucity of environmental data, frequently inconsistent data formats and potentially high data processing costs (e.g., infauna and video). There are additional resource constraints related to manpower and short-term funding cycles.

<u>Alaska Fisheries Science Center (AFSC) Sea Floor Habitat Research</u>

In 1996 the AFSC initiated studies specifically address the potential effects of fishing on the seafloor, benthic organisms and their habitat. The studies were directed at investigating the effect of fishing on the sea floor and evaluation of technology to determine bottom habitat type. A summary of the 1996 and 1997 studies and plans for 1998 are given below:

<u>Research in 1996 and 1997:</u>

<u>Experimental Trawling in the Eastern Gulf of Alaska</u>. A chartered manned submersible and chartered commercial trawl vessel were used to quantify changes to the sea floor caused by bottom trawling. Specific objectives were to document changes to epifauna and physical attributes to the sea floor caused by bottom trawling with tire-gear. The experiment took place in the Eastern GOA in rockfish habitat over hard bottom substrate during July and August 1996. Video footage was obtained from 10 trawl paths, including seven single tow paths, two triple tow paths and one seven tow path. Analysis of the videotape data focuses on habitat classification, sessile and motile epifauna in trawled versus untrawled transects, damage to epifauna, and comparisons of trawl bycatch with organisms in situ. Study sites were marked so that observations could be repeated in 1997.

In 1997, the 1996 submersible transects were repeated to document effects on seafloor habitat one year after trawling. In addition, the submersible was used in 1997 to observe trawl impacts on red tree coral, *Primnoa* spp. A trawl path was located at 365 m depth in Dixon Entrance where 2 t of red tree coral was caught during a 1990 trawl survey. The trawl path was identified by moved boulders and broken coral. Damage and abundance of coral in the trawl path will be compared to areas outside the trawl path.

Preliminary analysis of data collected in 1996 has been completed. The seafloor substrate at the experimental sites consisted of 92% pebble, 6% cobble and 2% boulder. The trawl path could be identified by furrows in the substrate 1-8 cm deep caused by the tire gear attached to the trawl foot rope. A total of 30 species (or larger taxonomic groups) of invertebrates were identified from the video. These species were categorized into sessile and motile groups. The seven sessile species were considered to provide “structural components of habitat”, because together with the boulders, they provided the only three dimensional relief on the sea floor. The sessile species were combined into four groups: three species of large erect sponge, morel sponge, finger sponge, and anthozoans (sea whips and anemones). The motile species were combined into five groups: asteroids, echinoids, holothurians, molluscs and arthropods.

Densities of undamaged large erect sponges, morel sponges, and anthozoans were significantly lower in trawled sites compared to reference sites. Densities of the small finger sponges were not significantly affected by trawling. Extensive incidences of damage were detected for the three species of large erect sponges, and for sea whips, but not for morel sponges, finger sponges or anemones. No significant differences in density of motile groups were detected, though the densities of arthropods and molluscs tended to be greater in trawled sites, possibly because of a scavenging response to disturbance by the trawl. No significant damage due to trawling was detected for any of the motile groups, with the exception of brittle stars. Trawl bycatch, as a percentage of individuals present in reference transects, were calculated for spot prawns (46%), asteroids (<1%), echinoids (<1%), holothurians (5%), and molluscs (<1%).

Trawl Effects in the Eastern Bering Sea. Experimental trawling was conducted in 1996 in the BS to improve understanding of the effects of bottom trawls on the soft-bottom benthos. Samples were collected with a NMFS 83-112 bottom trawl modified to improve retention of epifauna. In this study, epifauna are assumed to be indicators of sea floor attributes, given characteristically strong affinities for particular substrates. An historical analysis of commercial bottom trawl effort in the BS (1933-95) identified adjacent pairs of heavily fished and unfished 1 nmi^2 areas of the sea floor. Population densities and community structure in the two groups of stations will be compared. A color video system was attached to the experimental trawl and provided additional information on habitat features. In addition to inferences about trawl-related effects, this research will provide important information about the spatial variability in benthic communities and will serve as the basis for more rigorous manipulative investigations in the future.

During 1997 a GIS-based experimental design was developed to contrast biological and geological conditions before and after trawling with commercial gear and, if impacts were detected during 1997, to continue monitoring in subsequent years. Infauna samples were collected at an experimental (n=15) and a control (n=15) site during the pre-trawling phase. Additionally, sidescan sonar and video surveys were conducted in the experimental site, to characterize and identify sea floor attributes prior to trawling. Epifauna sampling and the trawling treatment will take place pending successful deployment of gear tracking - navigation system requisite to the experimental design.

Also in 1997, to evaluate potential chronic effects of trawling on infauna populations heavily fished and unfished stations (n=25 pairs), occupied during the 1996 study of epifauna, were quantitatively sampled with the 0.1 m^2 Sutar van Veen grab. Taxonomic processing of the samples is underway, under contract with the University of Alaska Fairbanks. Sidescan sonar and video surveys on both sides of the closed area boundary (58^o N., NE corner of management area 512) revealed sand waves, indicative of extensive reworking of the bottom by currents, as well as linear marks possibly caused by trawls. A sidescan reconnaissance survey in the very heavily fished Unimak “cod corridor”, characterized by harder substrates than the Bristol Bay sites, was also conducted.

Retrospective Analysis of Commercial Trawl Data and Benthic Community Structure. The objectives of this study are to utilize commercial trawl fishery data and trawl survey data to 1) describe the geographic and temporal patterns of trawl fishery effort in the GOA and Aleutian Island (AI) regions, 2) describe the major benthic communities by their component species and associations based on trawl survey data, and 3) to the extent possible, determine possible trawl fishery influences on benthic community structure by comparing benthic community structure in heavily trawled areas to lightly trawled areas. This study, initiated in 1996, is carried out via a grant to the Cooperative Institute for Arctic Research (CIFAR) at the University of Alaska, Fairbanks (UAF).

The spatial and temporal patterns of bottom trawl effort in the Gulf of Alaska (GOA) and Aleutian Islands (AI) were analyzed from 1990-1997. Haul data were from the National Marine Fisheries Service (NMFS) domestic observer database (NORPAC) and include gear type, latitude, longitude, and NMFS regulatory and reporting areas. Trawl locations were plotted annually and cumulatively by management areas in a geographical information system (ARCVIEW-GIS) map to aid in analysis of spatial and temporal patterns. Preliminary analyses have been conducted. Areas of high bottom trawl effort within the GOA occur in the Kodiak region where there have been directed fisheries targeting on Pacific ocean perch (*Sebastes alutus*), Pacific cod (*Gadus macrocephalus*), and flatfish. The Aleutian Island has had high trawl efforts for Atka mackerel (*Pleurogrammus monopterygius*) and Pacific ocean perch. The total numbers of observed tows, average tow time, and range of tow time for the years 1990-1997 have been computed for the GOA and the AI.

Changes in benthic assemblages in relation to trawl effort will be studied in the next phase of the study. Benthic community structure will be described from a database (RACEBASE), composed of species abundance and biomass from NMFS triennial and annual research surveys in the GOA and AI regions. Principal coordinate analysis will be applied to the species data and environmental parameters, including depth or strata.

<u>Evaluation of Technology to Determine Bottom Habitat Type</u>. Knowledge of the extent and distribution of different habitat types is necessary to make informed evaluations of the potential impact of fishing activity on seafloor habitat. Efficient methods to determine and describe bottom habitat are needed to obtain this information.

Laser line scan systems (LLSS) and hydroacoustic bottom typing systems were used in 1996 in areas that have been ground truthed. Data collected with LLSS was compared with historical (1991-1995) video and side scan sonar imagery over a well known area of bottom at depths similar to where trawl fisheries commonly occur. Also the feasibility of using LLSS to detect trawl tracks on the sea floor was evaluated. Trawl tracks were difficult or impossible to observe in well sorted sand mixed with shell hash, more easily observed in sand/silt mud bottom and clearly observable in soft bottom. The LLSS appears to fill a gap between side scan sonar and ROVs, is easily deployed and capable of observing some effects of trawling. An acoustic bottom typing system (QTC View Series 3, manufactured by the Quester Tangent Corporation, Sidney, B.C.) was used to begin an evaluation of the efficacy of remote sensing of sea floor properties in soft bottom areas of the BS and hard bottom areas of the GOA.

In 1997 the QTC system was deployed from the *Miller Freeman* during gear trials in Puget Sound and again in the Bering Sea during a routine hydroacoustic assessment of pollock (covering nearly 10,000 miles). In both cases, a classification catalog was developed and ground truth samples collected. Grab samples were also collected to evaluate the accuracy of the acoustic classifications. Also, selected tracklines were repeatedly surveyed to evaluate classification precision and potential effects of vessel speed. Finally, data sets were simultaneously collected at two frequencies using two *QTC View* systems and another more sophisticated hydrographic survey instrument (*ISAH-S*) to enable determination of optimum parameters for sea floor classification in the Bering Sea. A greatly refined *Series 4* has been developed by the QTC, with a feature set based heavily on AFSC experiences and research needs. A leased unit was evaluated in the Gulf of Alaska during summer 1997 aboard the NOAA ship *John Cobb* using a navigational echosounder (Simrad *EQ-50*). Analysis and a report detailing these results will be completed in FY 1998.

Workshop on Potential Effects of Fishing Gear on Benthic Habitat. About 30 individuals participated in a Sept. 1996 workshop including scientists from the Alaska Fisheries Science Center, NMFS Alaska Regional Office, U.S. Geological Survey, Alaska Department of Fish and Game (ADF&G), UAF, University of Washington (UW), and the National Undersea Research Center. The primary objectives of this workshop were to review the progress and preliminary results of studies initiated in 1996 and to discuss approaches and priorities for proposed research for 1997. Presentations included preliminary observations from a manned submersible of trawl effects on hard bottom areas in the Eastern GOA, an overview of field studies to examine bottom trawl effects in the BS, a description of methods to be used to examine benthic community structure and possible effects of trawling based on historical data in the GOA and AI, and video footage of how different types of trawl gear can effect seafloor habitats. Additional presentations included a review of fishing gear effects studies off the northeast United States and preliminary evaluations of the feasibility of using laser line scan systems, sidescan sonar, and hydroacoustic habitat mapping systems as research tools to examine fishing gear effects.

Effects of Trawling on Hard Bottom Habitat in the Aleutian Islands - Late in FY 1997, a project to study the effects of trawling on gorgonian coral habitat in the Aleutian Islands was initiated. Gorgonian corals were once a major component of the bycatch of the Atka mackerel fishery in Seguam Pass in the Aleutian Islands. However, after twenty years of intense fishing effort coral is now infrequently caught. The studies objectives are: 1) examine whether the corals in the heavily trawled areas of Seguam Pass are more damaged and less abundant than in nearby, less trawled, areas; and, 2)investigate whether fish and invertebrates use coral forests for shelter. The first year of the project was devoted to design and procurement of components needed to construct the towed camera body system. A system is currently being assembled which is patterned after the TACOS system developed by the Australian CSIRO Laboratory out of Hobart, Australia to study impacts on coral reefs. The system will be tested in Puget Sound or southeast Alaska in the late winter or spring of 1998.

AFSC Research Planned for 1998

A Description of Seafloor Habitat in a Heavily Trawled Region and a Protected Region of the Central Gulf of Alaska In 1986 the North Pacific Fisheries Management Council closed an area known as Marmot Flats near Kodiak, Alaska to bottom trawling. This area, encompassing 1500 km^2, was designated as an important rearing area and migratory corridor for juvenile and molting crabs. The closure is intended to assist in rebuilding severely depressed crab stocks by providing sanctuary to 85% of the Kodiak Island area red king crab stocks and 75% of the Tanner crab stocks. In addition to the crab resources, this area and the area immediately adjacent to it, have extremely rich stocks of groundfish including flathead sole, butter sole, Pacific halibut, arrowtooth flounder, Pacific cod, and several species of demersal rockfish. Consequently, the area immediately adjacent to the closure area is trawled extensively.

This closure provides a unique opportunity to study the effects of bottom trawling on a productive soft-bottomed marine ecosystem. Direct comparisons can be made between an area which is consistently trawled each year and an area where bottom trawling has been prohibited for at least twelve years. The proximity of the areas should allow for detection of fine-scale changes in infaunal and epifaunal composition, and microhabitat structure and abundance.

Use of a manned submersible is planned to assess changes to the seafloor caused by chronic trawling. Systematic video transects would be made along similar isobaths in the two areas. Controlling for depth should minimize diversity among epibenthic and infaunal species assemblages, and substrate composition. The seafloor habitat in both areas will be described in detail. All macrofauna, and physical characteristics of the seafloor will be quantified. Data from a minimum of twenty transects would be collected within each area. A sediment sample from each transect would be collected and analyzed for grain-size, and infaunal diversity and composition.

<u>Continuation of trawling effects studies in the Eastern Bering Sea.</u> The experimental approach adopted for a phase of this study requires exact real-time information on the position of both research and commercial trawls. During 1997 co-investigators with USGS were unable to provide this information with their equipment. In order to identify the proper equipment with the capability to provide this information, various alternatives will be evaluated in 1998.

During 1998, gear trials in Puget Sound will be conducted under conditions similar to those at the Bering Sea study sites. Three manufacturers will demonstrate gear tracking systems. Performance of each system will be evaluated by comparing system-based trawl positions with very accurate (<2-3 meters) determinations made by the test range. An independent consultant will plan, conduct and report test results. A representative commercial fishing vessel will be chartered for 12 days during which time each vendor will be given an opportunity to install and calibrate their equipment prior to standardized testing. Manpower and equipment costs directly related to the product demonstrations are the responsibility of each manufacturer. A mutually acceptable over-the-side transducer mount will be provided by the Government, as will all cabling between the transducer mount and the manufacturer supplied video display/navigation software in the wheelhouse. After completion of the analyses, test results will be submitted for publication in a peer-reviewed journal.

<u>Continued Evaluation of Technology to Determine Bottom Habitat Type</u>. The digitized echo returns collected in 1997 in the eastern Bering Sea using a QTC *ISAH-S* hydrographic instrument aboard the *Miller Freeman* will be analyzed by the QTC using proprietary methods. Results of these analyses will be used to optimize a *QTC View* acoustic sea floor classification system for the eastern Bering Sea. Simultaneous processing of *ISAH-S* data for an entire survey will greatly accelerate the otherwise iterative process of refining a *QTC View* classification catalog. The “raw” nature of the *ISAH-S* data also permits systematic evaluations of various hard coded options in the *QTC View* signal processing and sea floor classification algorithms which can then be optimized for a particular environment.

Specific objectives/deliverables include: (1) Phased processing of all *ISAH-S* data collected during the summer 1997 cruises of the *Miller Freeman* (38 and 120 kHz); (2) determine the optimum parameters for acoustic classification of the Bering Sea sea floor data; (3) evaluate the data to determine the optimum operational scenario for the *QTC View* system (*e.g.*, number of classification catalogs and number of substrate classes in each); (4) generate a habitat classification map and identify locations for calibration of the *QTC View* system; and (5) deliver a specially configured *QTC View Series 4* (upgrade), incorporating optima determined above. After these objectives are met, the *Miller Freeman*, chartered survey vessels or any other ships of opportunity will be able to create an optimum classification catalog and begin collecting synoptic data characterizing the eastern Bering Sea sea floor using a *QTC View* system.

Continuation of Effects of Trawling on Hard Bottom Habitat in the Aleutian Islands. Funding received in FY 1997 for this project was used to design and procure the components for the underwater towed camera body to be used for the project. All components and most of the supplies for the FY 1998 field work have been purchased and the towed system is being assembled. In FY 1998, the towed system will be tested in either Puget Sound or southeast Alaska to determine how it performs in areas of rough bottom and strong currents. The testing will be completed in late winter or spring of 1998. Once it is demonstrated that the towed system will perform as designed, the system will be deployed in Seguam Pass in the Aleutian Islands for 7 days in the summer of 1998 to record video observations of trawled and untrawled areas of gorgonian coral habitat and to investigate the utilization of those areas by key species of fish and invertebrates. The performance of the towed camera body will be evaluated and video observations analyzed and reported on in late 1998 or early 1999.

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9.2.4 Studies and Management Measures to Protect Habitat in Other Regions

South Atlantic and Gulf of Mexico

Longlines: Bottom longlines used to be one of the principle gears used to target snappers, groupers, wreckfish and other species in the Southeast U.S., and particularly within the jurisdiction of the South Atlantic Council (SAFMC). That Council's area of authority encompasses habitat ranging from the coral reefs of South Florida to the large expanses of sand and mud habitat with occasional rock and "live bottom" outcroppings and ledges off the coast of Georgia, South Carolina, and North Carolina. Between 1991 and 1997, significant restrictions were placed on the use of bottom longlines as part of Amendments 3 through 9 to the FMP for Snappers/Groupers. Pelagic longlines are used for a number of species in the region and are managed under different regulations.

One restriction that was developed in Snapper/Grouper Amendments 4 prohibited the use of bottom longlines for wreckfish, now exclusively a deep water vertical hook and line fishery (300-400 fathoms). The prohibition was implemented because of gear conflicts and potential for habitat damage as stated in the Council plan. The plan provides the following rationale:

Longline cable on the bottom has the potential to break some of the ledges, overhangs and associated organisms, and otherwise damage the habitat on which the wreckfish depend. Habitat damage caused by the longlines would violate the SAFMC habitat policy and should be avoided (SAFMC Amendment 4 to the Snapper/Grouper Plan, pg.53). In 1992, the SAFMC prohibited the use of bottom longlines to fish for snappers, groupers, sea basses, and other finfish in the complex in South Atlantic waters inside of 50 fathoms. The following habitat protection rationale was offered by the SAFMC:

Habitat damage and intense competition among users are problems that arise when longline gear is used within 50 fathoms where significant live bottom occurs and where competition with other hook and line vessels occurs. The Council concluded that this gear is appropriate for use in the deep-water snowy grouper/tilefish fishery where much of the bottom is mud with sparse live bottom areas (pg 55, SAFMC Amendment 4 to the FMP for Snapper/Groupers). And on page 56: "This regulation essentially segments the mid-shelf and the deep-water complex to the bottom longlines. This measure was supported during the public hearing process and the Council concluded that prohibiting use of longline gear within 50 fathoms will prevent the problems of habitat damage and intense competition while at the same time allow fishermen using this gear to continue fishing in deeper water. This action effectively limits longlines to targeting the deep water component of the snapper grouper fishery and keeps the use of longlines outside of the rough bottom habitat." More recently, for enforcement reasons, the South Atlantic Council prohibited fishing with bottom longline gear for nearly all species in the Snapper/Grouper complex, the single exceptions are tilefish and snowy grouper which are found in mud and sand areas with little sensitive habitat (Snapper/Grouper Amendment 6).

The Gulf of Mexico Council has partially followed the SAFMC's lead on prohibiting bottom longlines inside of 50 fathoms. Prohibitions in the waters of the Gulf of Mexico are in state waters in Florida and in federal waters within habitat protection areas. It is noteworthy that in nearly all South Atlantic and Gulf of Mexico waters, the relatively flat continental shelf means that depths do not exceed 50 fathoms until at least 30 to 70 miles from the coastline. The shelf off South Florida is an exception, however, where depths greater than 50 fathoms can be reached within 3-10 miles of the coastline.

Fish Pots and Traps: Fish pots have been used in the South Atlantic and Gulf of Mexico to target black sea bass as well as numerous snapper and grouper species. The most extensive restrictions placed on fish traps were been put in place in state of Florida and federal waters managed by the South Atlantic

Council. In 1991, the SAFMC approved restrictions on the use of baited and non-baited fish pots and traps as part of Amendment 4 to the Council's Snapper/Grouper FMP. Fish pots for snapper and grouper were prohibited in all waters, with one exception for the use of pots for black sea bass north of Cape Canaveral (with a 2 ft by 2ft by 3 ft maximum size restriction for pots). The stated rationale in Amendment 4 for taking such an action was as follows:

There is some evidence that fish trapping causes habitat damage where fish traps are set in "trawls" on live bottom and where grappling hooks are dragged across live bottom to retrieve them. Testimony and video records of damaged Oculina reefs off Palm Beach County, Florida shown to the Council at the February 1991 meeting, depicted significant and measurable damage to coral reef and live bottom communities. These activities leave an imprint of the trap upon the bottom communities and trenches caused by grappling hooks dragged over the bottom for the purpose of locating and recovering traps. Lost traps not only continue to fish, as it has been pointed out in the ghost trap discussion, but may contribute secondary habitat damage by becoming mobilized at times of storm activity and impacting delicate bottom communities. These problems cannot be alleviated by trap design modifications even if such modifications could be enforced. (SAFMC's Snapper/Grouper Plan, Amendment 4. April 1991 page 73-74). Concerns over ghost fishing and data showing that fish pots were taking an excessive share of the harvest from traditional gears were also reasons for the SAFMC's actions to ban fish pots.

While the Gulf of Mexico Council opted not to adopt parallel regulations in the face of the South Atlantic's prohibition on fish pots, the Gulf Council concurrently placed size, area, and number restrictions on the use of fish pots, partly for habitat protection objectives. South Atlantic and Gulf of Mexico Council documents cite information used to back their restrictions on fish pots and longlines. Often, evidence presented to the Council from underwater videos (probably available from SAFMC) is cited as well as scientific studies.

Literature from Other Regions

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9.2.5 Review of Management Measures and Proposed Next Steps

A review of existing fishery management measures as they relate to protection of EFH was provided in Section 1.4. The Council has a long history of protecting fish habitat. Area closure to trawling and dredging in the Bering Sea and Aleutian Islands area serve to protect HAPC from potential adverse impacts caused by these gear types. Other management measures were designed to reduce the impact of fishing on marine ecosystems. Catch quotas, bycatch limits, and gear restrictions control removals of prey species. Area closures around marine mammal rookeries and haulouts reduce fishery interactions with these predators.

Current research on the impacts of fishing gear on habitat was summarized in Section 9.2.2. Studies are being done to compare seafloor habitats in areas heavily trawled with areas that have had little trawl effort. Separate studies are underway in the GOA, Bering Sea, and Aleutian Islands.

The next step in this process (Phase 2) is to identify habitat areas of particular concern (HAPC) for each fishery management plan (FMP). The Alaska region has FMPs for Gulf of Alaska groundfish, BSAI groundfish, BSAI king and Tanner crab, Alaska scallops, and Alaska salmon. Proposals to amend the FMPs are being solicited to 1) identify HAPC, and 2) establish conservation measures to minimize, to the extent practicable, adverse impacts from fishing on HAPC. Additional details and guidelines for HAPC proposals were developed by the NMFS Core Team based on information supplied in Section 11 of this document. Copies of the guidelines are available from the Council office. In October 1998, the Council will prioritize the proposals and task staff with analyses. Final action on these amendments is scheduled for June 1999. Additional details of the proposal cycle are listed in Section 1.5.

9.3 Cumulative Impacts Analysis

The guidelines state that, to the extent feasible and practicable, FMPs should analyze how fishing and non-fishing activities influence habitat function on an ecosystem or watershed scale. This analysis should describe the ecosystem or watershed; the dependence of the managed species on the ecosystem or watershed, especially EFH; how fishing and non-fishing activities, individually or in combination, impact EFH and the managed species; and how the loss of EFH may affect the ecosystem**.** An assessment of the cumulative and synergistic effects of multiple threats, including the effects of natural stresses (such as storm damage or climate-based environmental shifts), and an assessment of the ecological risks resulting from the impact of those threats on the managed species' habitat should also be included. For the purposes of this analysis, cumulative impacts are impacts on the environment that result from the incremental impact of an action when added to other past, present, and reasonably foreseeable future actions, regardless of who undertakes such actions. Cumulative impacts can result from individually minor, but collectively significant actions taking place over a period of time.

Cumulative impacts from fishing. In addressing the impacts of fishing on EFH, Councils should also consider the cumulative impacts of multiple fishing practices and non-fishing activities on EFH, especially, on habitat areas of particular concern. Habitats that are particularly vulnerable to specific fishing equipment types should be identified for possible designation as habitat areas of particular concern.

Mapping cumulative impacts. A GIS or other mapping system should be used to support analyses of data. Maps depicting data documenting cumulative impacts identified in this paragraph should be included in an FMP.

Research needs. If completion of these analyses is not feasible or practicable for every ecosystem or watershed within an area identified as EFH, Councils should, in consultation with NMFS, identify in the FMP priority research areas to allow these analyses to be completed. Councils should include a schedule for completing such research. Such schedule of priority research areas should be combined with other EFH research needs.

The NPFMC and the Secretary of Commerce have taken appropriate actions when threats to fish habitat have been identified. These include cumulative effects from fishing activities and non-fishing activities. Cumulative effects have been examined in the Stock Assessment and Fishery Evaluation (SAFE) reports, which are produced annually for the crab, scallop, and groundfish fisheries. In addition, the plan teams prepare an Ecosystem Considerations Section to the SAFE reports. These reports identify specific ecosystem concerns that are considered by fishery managers for maintaining sustainability of marine ecosystems. The NMFS Alaska regional office has released for public review a supplemental Environmental Impact Statement (SEIS) for the Alaska groundfish fisheries that contains a description of all impacts due to fishing (NMFS 1998).

Cumulative impacts from non-fishing activities are monitored during the NMFS and State of Alaska permit review process. Development of habitat computer databases and GIS location maps will greatly assist this process. Coordination with other agencies will be required. For more information, see Section 6.0, containing NMFS recommendations on the description and identification of EFH.